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Migratory Routes of Adult Sockeye Salmon, *Oncorhynchus nerka*, in the Eastern Bering Sea and Bristol Bay

RICHARD R. STRATY

SEATTLE, WA
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Rogers C. B. Morton, Secretary

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Robert M. White, Administrator

National Marine
Fisheries Service
Robert W Schoning, Director

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Migratory Routes of Adult Sockeye Salmon, *Oncorhynchus nerka*, in the Eastern Bering Sea and Bristol Bay[1]

RICHARD R. STRATY[2]

ABSTRACT

The stocks of sockeye salmon, *Oncorhynchus nerka*, in Bristol Bay, Alaska, are produced in the lakes and streams of 10 major river systems, which discharge into the bay over a shoreline distance of 193 km.

The establishment of fishing areas, the determination when fishing may be permitted, and the effect of exploiting simultaneously several stocks of sockeye salmon require knowledge of the migratory pattern of the individual stocks comprising the run to Bristol Bay during spawning migration. Various mark-and-recapture experiments and exploratory fishing in the eastern Bering Sea and Bristol Bay provide a picture of the migratory pattern of Bristol Bay sockeye salmon from approximately long. 170°W to the head of Bristol Bay.

The main migration route of all stocks of Bristol Bay sockeye salmon is in the offshore waters of the southern half of the entrance to the bay and in the southern half of the bay itself. All stocks remain in the offshore waters until within 32 to 80 km of their home-river systems. Segregation according to river of origin apparently began in the offshore waters as much as 200 km from the mouths of the home-river systems and appeared to progress to the head of Bristol Bay.

INTRODUCTION

Salmon management in the Pacific Northwest has long been based on the premise that salmon homing to various river systems or principal tributaries of river systems constitute individual production units or stocks.[3] Because of its reproductive isolation and attendant adaptive processes, each stock has its own unique requirements for spawning, incubation of eggs, and rearing, and therefore must be managed separately insofar as it is practical to do so.

Thus, management of stocks of Pacific salmon, *Oncorhynchus*, in North America has resulted in a multiplicity of regulatory districts, each of which is associated with a major river, bay, or strait. Ideally, the times and places that salmon are taken would be controlled within each district so that individual stocks would be harvested independently of others, each in accordance with its own requirements and level of productivity. In pursuit of this ideal, fishery biologists have directed their efforts toward determination of the routes and times of the spawning migrations of major stocks. These efforts have revealed that most salmon stocks are completely separate from others only when they become segregated in the spawning tributaries.

The establishment of fishing areas, the determination of times when fishing may be permitted, and the assessment of the effects of exploiting simultaneously several salmon stocks having differing levels of productivity remain especially vexing problems. This is particularly true for the important stocks of sockeye salmon, *O. nerka*, of Bristol Bay, Alaska where five districts are designated for management and regulation of the fishery—Togiak, Nushagak, Naknek-Kvichak, Egegik, and Ugashik. The Togiak, Egegik, and Ugashik districts have single-river systems,[4] which discharge into Togiak, Egegik, and Ugashik Bays; the Nushagak district has four major river systems which discharge into Nushagak Bay; and the Naknek-Kvichak district has three river systems which discharge into Kvichak Bay (Fig. 1).

Over the years the boundaries of each district have undergone a number of changes which have generally

[1]Based in part on a thesis submitted to the graduate school of Oregon State University, Corvallis, in partial fulfillment of the requirements for the degree of Doctor of Philosophy, June 1969.

[2]Northwest Fisheries Center, Auke Bay Laboratory, National Marine Fisheries Service, NOAA, Auke Bay, AK 99821.

[3]The term "stock" as used in this paper is applied to the population of salmon of a given species inhabiting a specific river system or main tributary during the spawning and rearing stages of the life cycle. This use of the term is, for the most part, consistent with current management practices.

[4]Each lake or group of connected lakes and its outlet to the ocean is termed a "system" and designated in this report by the name of the outlet or trunk river. For example Coville, Grosvenor, Brooks, and Naknek lakes are connected to the ocean through the Naknek River, and the system is therefore called the Naknek.

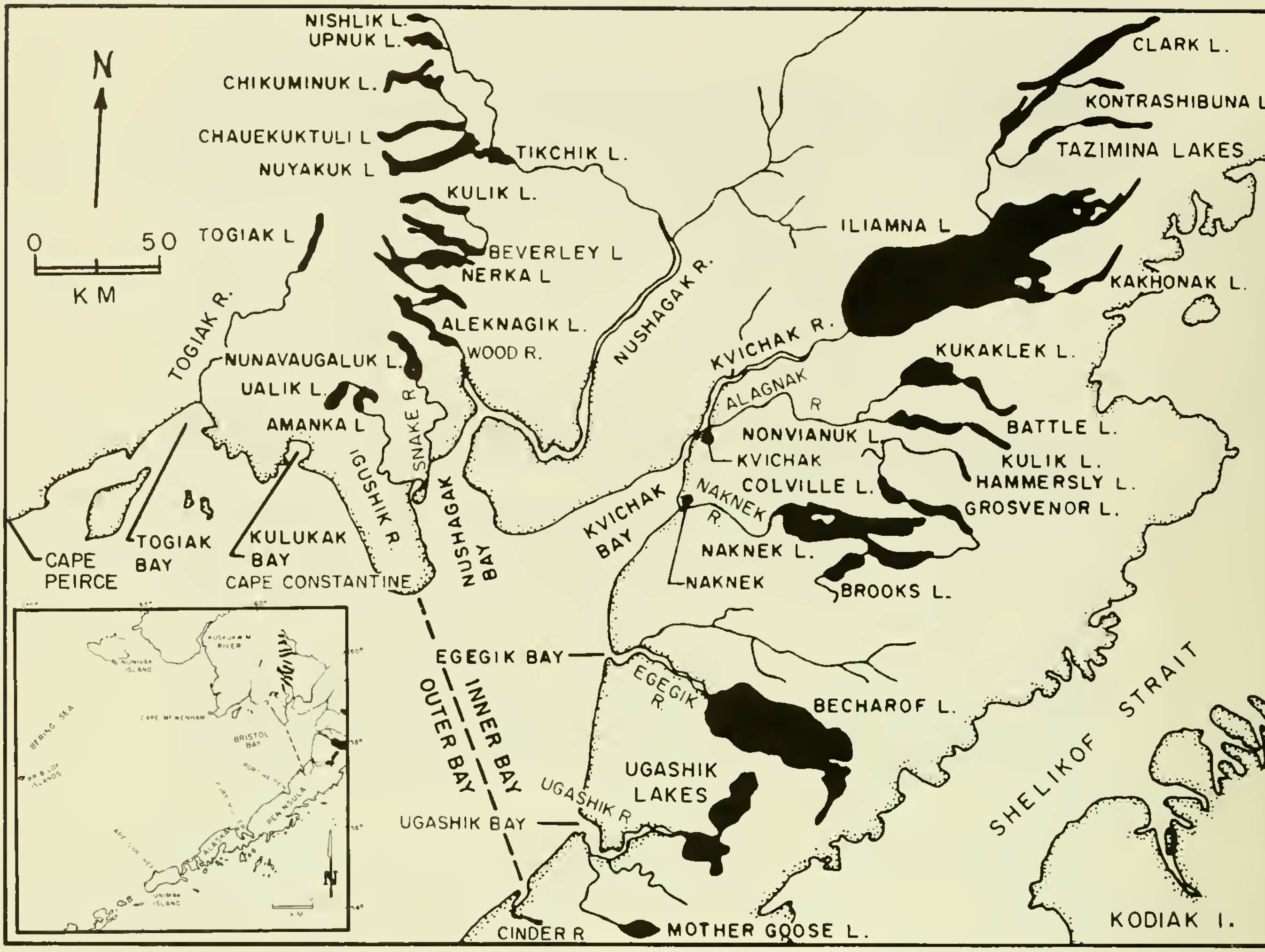

Figure 1.—Principal sockeye salmon river systems in Bristol Bay.

reduced the size of the area where fishing is permitted and have confined the fishing fleets closer to the river mouths. The earliest changes were made on the largely intuitive assumption that the fish nearest to a river mouth were fish produced in that river system.

To establish a more scientific basis for setting up district boundaries, mark-and-recovery experiments which defined areas of concentrations of the major stocks of sockeye salmon were carried out in the inner region of Bristol Bay in the 1950's and early 1960's by the Bureau of Commercial Fisheries (now the National Marine Fisheries Service, NOAA); the Fisheries Research Institute, University of Washington, Seattle; and the State of Alaska Department of Fish and Game. The most extensive of these were conducted from 1955 through 1959, principally by the Bureau of Commercial Fisheries. In addition, a considerable amount of salmon tagging and exploratory fishing has been carried out in outer Bristol Bay and the eastern Bering Sea by the United States and Japan.

In this study, I summarize the results of the inshore and offshore tagging and exploratory fishing and describe the probable routes followed by individual river stocks of sockeye salmon during spawning migration from approximately long. 170°W in the Bering Sea to the head of Bristol Bay.

THE SOCKEYE SALMON FISHERY OF BRISTOL BAY

Sockeye salmon runs to Bristol Bay are among the largest on the North American Continent. More than 50 million adult salmon have returned to spawn in the river and lake systems of this area in a single year. The individual stocks that make up the annual run are produced in the lakes and streams of 10 major river systems which discharge into the bay over a shoreline distance of 193 km (Fig. 1).

The spawning migration starts in the distant ocean in early May. Salmon move directly toward the Aleutian Islands passes from their feeding grounds in the North Pacific Ocean and then eastward in the Bering Sea to Bristol Bay at a rate of about 48 km per day (Hartt 1962). Small numbers of fish are on the fishing grounds by mid-June, and the run usually reaches peak proportions between 1 and 10 July. By late July most of the fish have entered their respective river systems, and few are left on the fishing grounds.

Commercial fishing in Bristol Bay is done almost entirely with gill nets. The nets are set from one- or two-man boats and drift with the tide (drift nets) or are staked or anchored along the beaches (set nets). The fishery is so intense and efficient that it takes almost all of the fish in a district during an open fishing period. Because of this, the fishery in each district is closed periodically so that spawners from all time segments of the run can escape to the stream.

The day-to-day progress and size of the run through each fishing district is monitored by the Alaska Department of Fish and Game, which exercises control over Alaska fisheries. Test-fishing is done during the closed periods and in closed fishing areas both upstream and seaward of the fishery to obtain immediate indices of the numbers of fish entering and escaping the fishery. Finally, sample counts are made from observation towers on each bank of all the major rivers entering the bay to obtain an accurate estimate of spawning escapements.

DETERMINING THE DISTRIBUTION AND MIGRATORY PATTERNS OF BRISTOL BAY SOCKEYE SALMON

Three different types of investigations have demonstrated that sockeye salmon in the Bering Sea near long. 170°W and lat. 60°N are bound for Bristol Bay. These investigations involved (1) studies of scale characters, morphological characteristics, and parasite infestations (Margolis et al. 1966); (2) studies of the direction of movement of sockeye salmon caught in gill nets (Barnaby 1952) and purse seines (Hartt 1962); and (3) tagging experiments (Hartt 1962, 1966; Kondo et al. 1965).

In this section I examine data from these published sources and from unpublished tagging studies done in Bristol Bay proper to describe the distribution and migration pattern of stocks in offshore and inshore areas. In addition, I use changes in the age group structure of fish tagged at various locations to show the distribution of several major sockeye stocks in the inshore area. The offshore region includes that area of the Bering Sea east of long. 170°W and south of lat. 60°N to a line drawn between Cape Constantine and the Cinder River (Figs. 1 and 2). The inshore area includes the remaining area to the river mouths.

Offshore Distribution

The distribution and migration routes of sockeye salmon in the offshore area have been determined from the results of exploratory fishing along north-south transects by research vessels of the United States and from the locations of recapture of sockeye salmon tagged in the offshore area by the United States and Japan. The sources of data and the years involved in the exploratory fishing and the tagging I consider here are given in Appendix Table 1.

Exploratory Fishing.—The exploratory fishing was done in offshore waters of the Bering Sea intermittently over a period of 28 yr. In most cases gill nets of various lengths and mesh sizes were the principal gear, although purse seines and longlines were also used.

Results from 8 of the years of this exploratory fishing (all with gill nets) are used to show distribution in the offshore area. These years were selected because (1) fishing was carried out during the period of the spawning migration when sockeye salmon are most abundant (June and July); (2) fishing was fairly systematic, usually on consecutive days at stations located along given transects (Fig. 2); and (3) the transects fished provided the most extensive coverage available.

In some years fishing was carried out along a given transect two or three times. In these instances, catch data are used to examine the consistency of the sockeye salmon distribution and therefore the migration route at various times during the spawning migration. Fishing was also carried out along long. 170°W in 3 different years, making possible a comparison of sockeye salmon distribution between years with runs of different magnitude.

Results of Exploratory Fishing.—The gill net catches of sockeye salmon along the six transects established across the approaches to Bristol Bay in the offshore area show that the abundance of sockeye salmon increases and then decreases with increasing distance in a northerly direction offshore from the northwestern side of the Alaska Peninsula and the northeastern Aleutian Islands (Figs. 3-10). With one exception (28 June-3 July 1940—Fig. 6) this pattern was consistent for all years and along all of the transects.

The area of greatest abundance of sockeye salmon along the long. 170°W transect was between 161 and 322 km offshore in 1958, 1959, and 1961 (Figs. 3-5). Catches decreased nearer the south side of the Pribilof Islands. In 1959 and 1961 large catches were made north of the Pribilof Islands (Figs. 4 and 5), but they decreased with increasing distance to the north of these islands. A comparison of the abundance of fish along the long. 170°W transect at approximately the same locations, but a week or two apart, shows that the pattern of distribution remained essentially the same (Fig. 5). This 2-wk period is sufficient for the major portion of the total Bristol Bay sockeye salmon run to pass through this area. These results, plus the fact that the distributions of sockeye salmon in the 3 yr were similar, suggest that this pattern may not vary greatly during the time the entire run passes through this area or from year to year.

Along the transect between Cape Mordvinof and the Pribilof Islands the size of the catches increased,

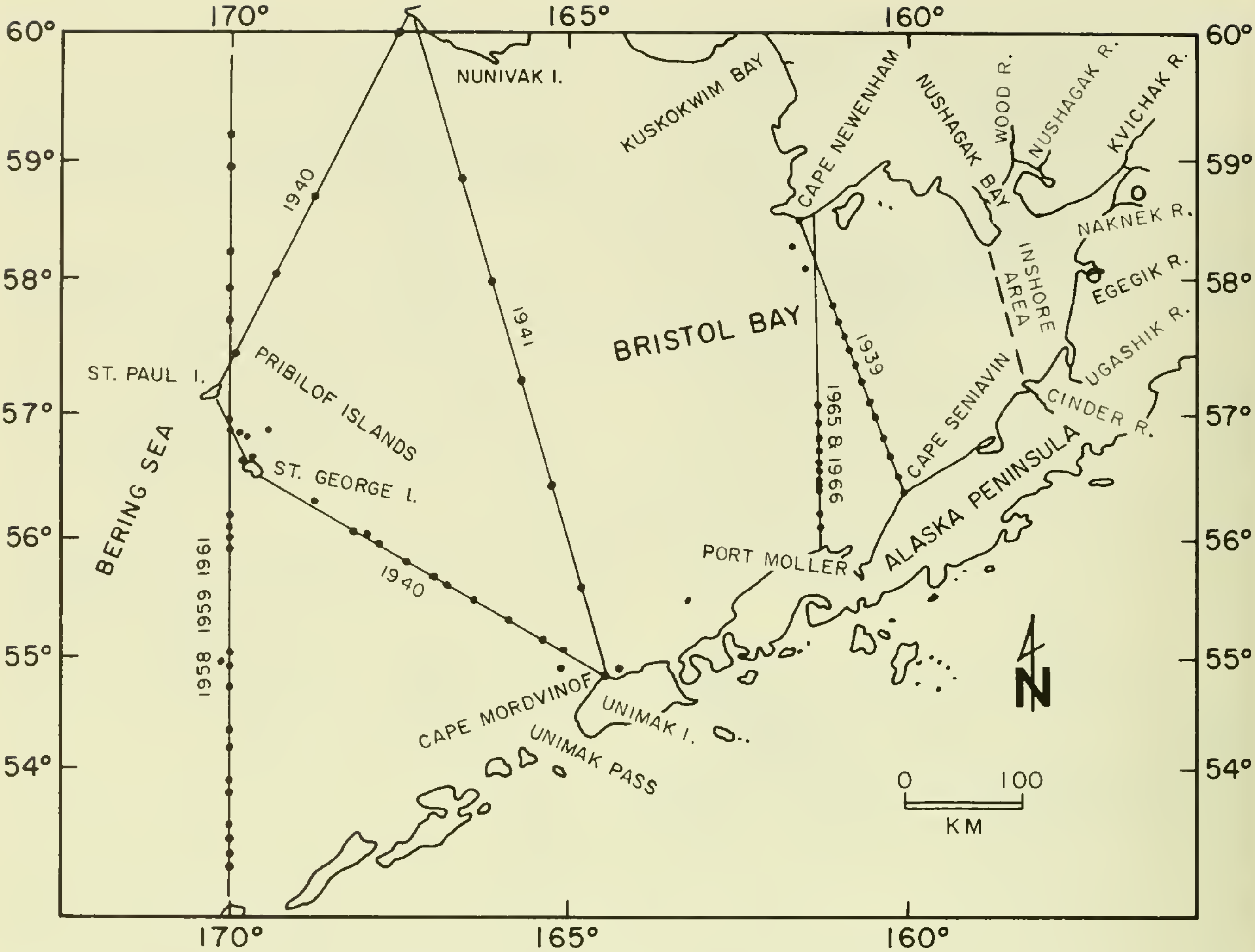

Figure 2.—Transects in the eastern Bering Sea and outer Bristol Bay where exploratory fishing was carried out in the 8 yr selected for study to determine the distribution of sockeye salmon in offshore area of Bristol Bay. (See Appendix Table 1 for source of data.)

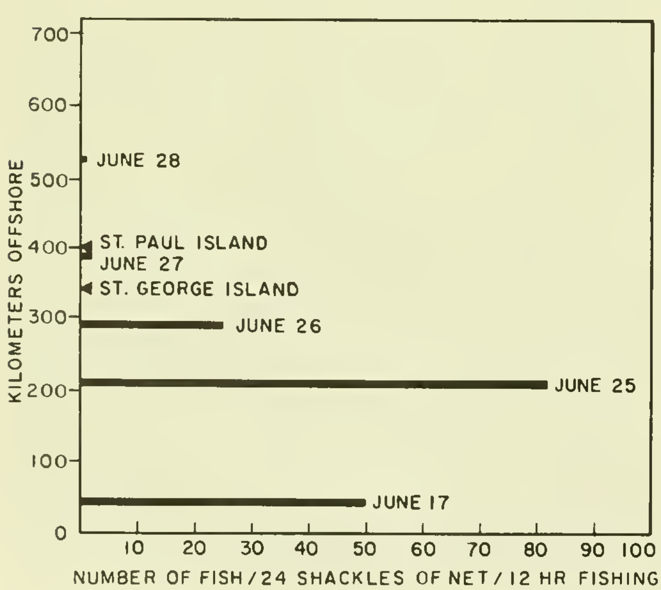

Figure 3.—Gill net catches of sockeye salmon along approximately long. 170°W, 17-28 June 1958. Each shackle of net was about 50 fathoms. (See Appendix Table 1 for source of data.)

and then decreased with increasing distance offshore (Fig. 6). This is consistent with the pattern of distribution along the long. 170°W transect. Catches near the Pribilof Islands were again small. North of the Pribilof Islands, however, catches were large but decreased at locations farther offshore toward Nunivak Island (Fig. 7).

The above results show that large concentrations of sockeye salmon returning to Bristol Bay occur in two bands: one in the offshore waters between the Aleutian and Pribilof Islands and the other in waters north of the Pribilof Islands.

Catches along the transect between Cape Mordvinof and Nunivak Island in 1941 also show two bands or regions of heavy abundance (Fig. 8). This pattern of

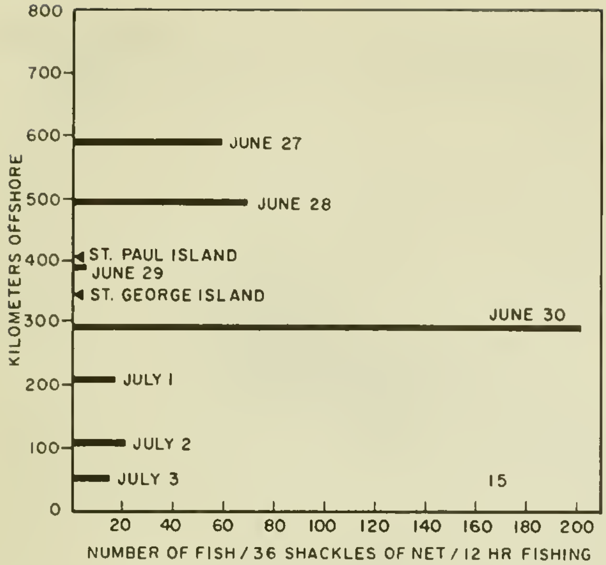

Figure 4.—Gill net catches of sockeye salmon along approximately long. 170°W, 27 June-3 July 1959. Each shackle of net was about 50 fathoms. (See Appendix Table 1 for source of data.)

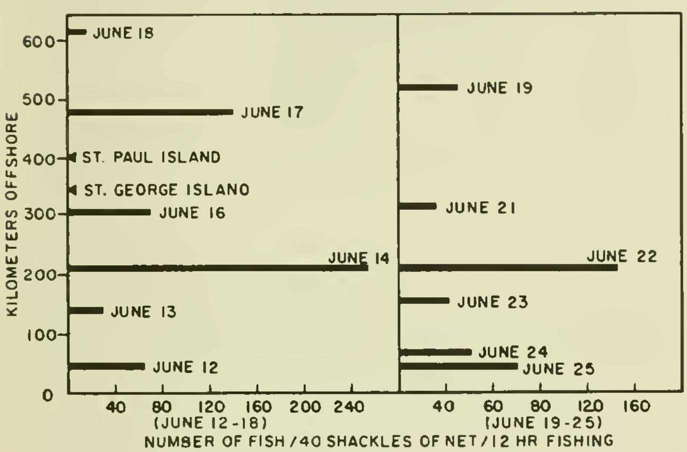

Figure 5.—Gill net catches of sockeye salmon along approximately long. 170°W, 12-25 June 1961. Each shackle of net was about 50 fathoms. Note: The net was fished for only 7 h on 21 June; the net used on 25 June had only 39 shackles. (See Appendix Table 1 for source of data.)

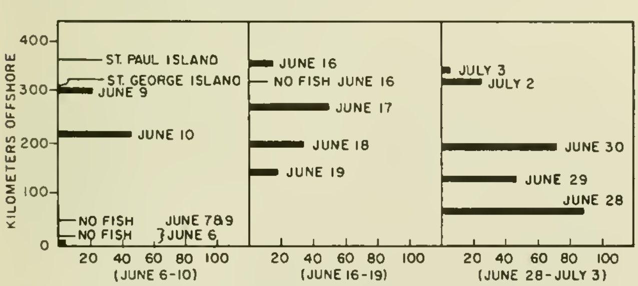

Figure 6.—Gill net catches of sockeye salmon between Cape Mordvinof and Pribilof Islands, 6 June-3 July 1940. Note: Fishing time was not specified, but I assumed that it was the same for each set. (See Appendix Table 1 for source of data.)

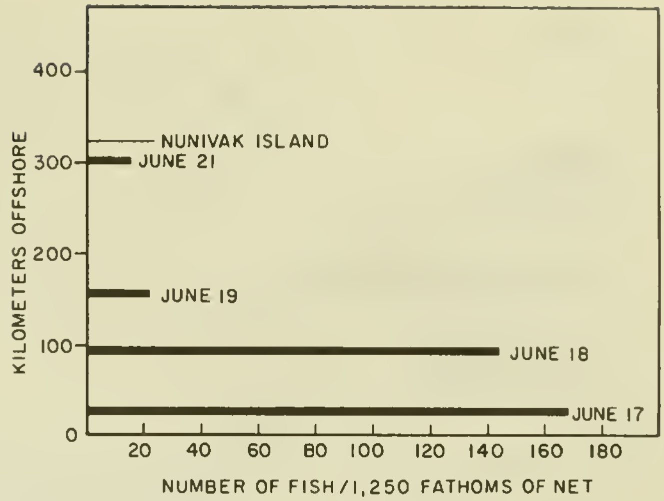

Figure 7.—Gill net catches of sockeye salmon between Pribilof Islands and Nunivak Island, 17-21 June 1940. Note: Fishing time was not specified, but I assumed that it was the same for each set. (See Appendix Table 1 for source of data.)

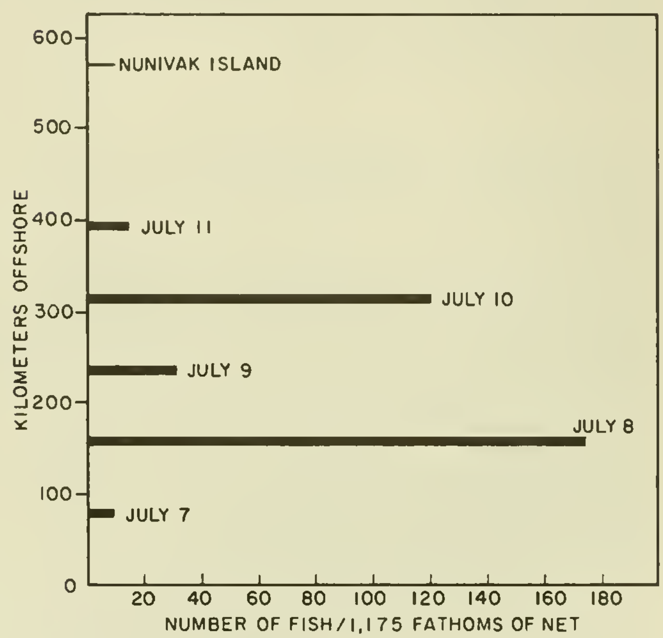

Figure 8.—Gill net catches of sockeye salmon between Cape Mordvinof and Nunivak Island, 7-11 July 1941. Note: Fishing time was not specified, but I assumed that it was the same for each set. (See Appendix Table 1 for source of data.)

distribution is consistent with that shown along long. 170°W.

Gill net catches of sockeye salmon at each location along long. 161°30′W in 1965 and 1966 show that the abundance again increases and then decreases with increasing distance offshore to the north, suggesting there is only one region of high abundance along this transect (Fig. 9). This distribution is consistent with

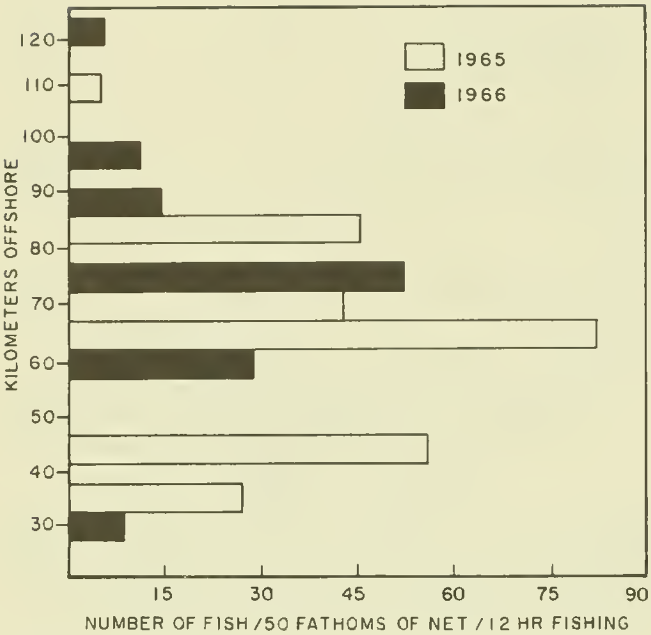

Figure 9.—Gill net catches of sockeye salmon along approximately long. 161°30′W, 24 June-6 July 1965 and 1966. (See Appendix Table 1 for source of data.)

that shown by catches along the transect between Cape Seniavin and Cape Newenham in 1939 (Fig. 10). Here, the distribution remains essentially the same from early to late July. The greatest abundance of sockeye salmon along both transects was offshore but in the southern half of Bristol Bay. The pattern of abundance of sockeye salmon in gill nets fished by the Japanese training ship *Oshoro Maru* in 1967 and 1969 (Hokkaido University, The Faculty of Fisheries 1968, 1970) in the western part of Bristol Bay substantiated their high abundance in this region during the spawning migration.

The abundance of sockeye salmon along all transects was greatest in offshore waters of the eastern Bering Sea and in Bristol Bay itself.

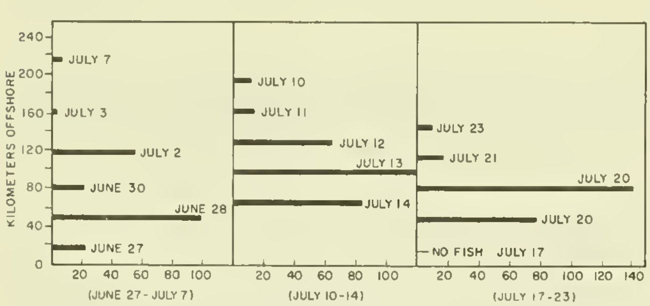

Figure 10.—Gill net catches of sockeye salmon between Cape Seniavin and Cape Newenham, 27 June-23 July 1939. Note: Fishing time was not specified, but I assumed it was the same for each set. (See Appendix Table 1 for source of data.)

Synopsis: Distribution of Sockeye Salmon in the Eastern Bering Sea and Outer Bristol Bay during Spawning Migration.—From the foregoing results, it is clear that sockeye salmon bound for Bristol Bay do not follow a route close inshore, at least not westward of Cape Seniavin. After entering the Bering Sea via Aleutian Islands passes, the salmon apparently move north for a considerable distance before moving east into Bristol Bay. This northward movement into the offshore waters of the Bering Sea was reported by Hartt (1966). Early tagging experiments in the vicinity of Cape Seniavin by Gilbert (1923) showed that even here Bristol Bay sockeye salmon were not present in the coastal waters. These results were confirmed through additional tagging studies carried out in the same area in 1925 by Rich (1926).

The above results have been summarized in Figure 11 to provide a synopsis of the distribution of sockeye salmon during migration through the eastern Bering Sea and outer Bristol Bay.

Offshore Tagging.—To determine if individual sockeye stocks or groups of stocks comprising the run to Bristol Bay were segregated according to river of origin while in the offshore area, I analyzed the published results of 6 yr of salmon tagging carried out at various locations in the eastern Bering Sea and outer Bristol Bay (Fig. 12, Appendix Table 1). These years were selected because the tagging sites were widely distributed over the approaches to Bristol Bay; many of the sites of tagging were east of long. 170°W, and tagged fish from most sites were recaptured in the Bristol Bay fishery.

Tag recoveries are grouped by regulatory fishing district, i.e., Nushagak, Naknek-Kvichak, Egegik, and Ugashik. The sockeye salmon migrating to each district are treated as individual populations, even though several major river systems discharge into some of the districts. The assumption is made in the analysis that tagged fish recaptured in a particular fishing district were actually bound for the major river systems of that district.

In analyzing the recovery data, I adopted the hypothesis of like distribution for all sockeye salmon stocks of Bristol Bay origin, i.e., that sockeye salmon tagged at the various offshore sites occurred in the same proportion as they did in the total run to Bristol Bay. To test this hypothesis, I used chi-square analysis to compare the actual tag recoveries with the expected recoveries in individual fishing districts and also when the districts were grouped according to location, i.e. whether fishing districts were located on the west side (Nushagak) or east side (Naknek-Kvichak, Egegik, and Ugashik) of Bristol Bay. Probability values of less than $P = 0.05$ were considered to indicate unlike distribution (segregation) of sockeye salmon stocks offshore.

The expected number of tag recoveries from individual or grouped fishing districts were computed from the following:

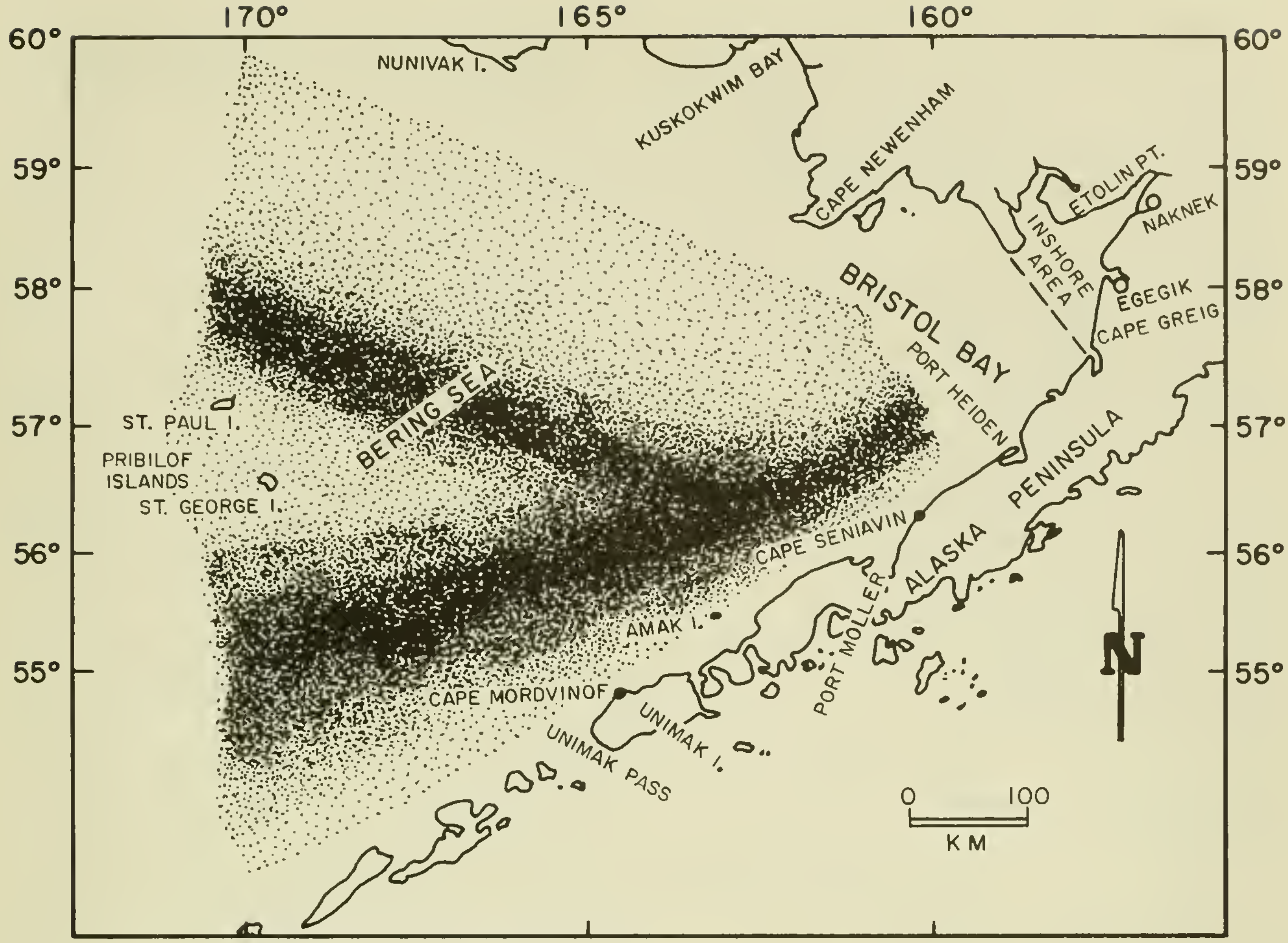

Figure 11.—Distribution of sockeye salmon in eastern Bering Sea and Bristol Bay during spawning migration, showing main migration route. Distribution was determined from results of exploratory fishing.

$$\hat{R}_i = \left(\frac{R}{C}\right) \bullet \left(C_i\right)$$

where

$\hat{R}_i$ = expected number of tag recoveries from the ith fishing district

R = tag recoveries in total Bristol Bay commercial catch

C = total Bristol Bay commercial catch

C_i = catch in the ith fishing district.

For most years, the recoveries from several tagging locations have been grouped for computation of expected recoveries (Table 1). This was done because tagging was often carried out in the same general area or to provide a larger number of recoveries in the analysis.

Several factors inherent in the commercial fishery could cause the smaller tagged fish to be more vulnerable to capture than untagged fish of the same size.

Commercial fishing in all districts of Bristol Bay is done entirely with gill nets. Working with Fraser River sockeye salmon, Peterson (1954) showed that gill nets of the type and mesh size (13.65-cm stretch measure) used in Bristol Bay were selective for size of fish. Differences in the size composition between the commercial catch and the escapement indicate that the gill nets used by Bristol Bay fishermen are selective for the larger .3 fish[5] (Mathisen 1971). Apparently, many of the smaller .2 fish are able to pass through the gill nets and escape.

Ricker (1958) found that fish tagged with plastic disk tags, the type used most frequently in the offshore tagging studies, are more vulnerable to capture by gill nets than untagged fish because the twine of the net catches under the disk. Because of the tag, a

[5]The terms .2 and .3 refer to the number of winters a salmon has spent in the ocean. A numeral to the left of the dot indicates the number of winters the fish has spent in fresh water and the numeral to the right of the dot the number of winters in the ocean. Thus a 2.3 adult salmon is one which has spent 2 winters in fresh water and 3 winters in the ocean and is in its sixth year of life. The use of this method (European method) for designating the age of adult Pacific salmon (marine life only) was proposed by Koo (1962).

Table 1.--Actual numbers and expected numbers (in parentheses)[1/] of tags recovered in four Bristol Bay fishing districts from sockeye salmon released (see Fig. 12 for tagging sites) in the Bering Sea and Bristol Bay by the United States and Japan in 1957, 1958, 1960, 1961, 1964, 1965. (See Appendix Table 1 for sources of data.)

Year, country, and tagging site (lat. and long.)	Date of tagging	Recoveries by fishing district: West side	East side		
		Nushagak	Naknek-Kvichak	Egegik	Ugashik
1957--United States					
Midway between Unalaska Island and Pribilof Islands	17 June	0	1	0	0
55°37'N, 168°33'W	19 June	0	3	0	0
56°00'N, 170°00'W	20 June	0	3	1	0
56°12'N, 169°54'W	21 June	0	0	1	1
56°50'N, 170°13'W	22 June	0	3	0	0
56°10'N, 171°08'W	23 June	0	4	3	0
54°21'N, 166°55'W	29 June	0	1	0	0
Total		0 (1.65)	15 (15.42)	5 (2.74)	1 (1.18)
1958--United States					
95 miles west of St. George Island	16 June	0	1	0	0
25 miles south of St. Paul Island	22 June	0	0	1	0
6 miles north of St. George Island	24-27 June	0	3	7	5
5 miles north of St. George Island	25-27 June	2	6	2	1
Total		2 (10.36)	10 (8.76)	10 (4.75)	6 (4.12)
1960--United States					
53°25'N, 168°51'W	20 June	0 (1.11)	7 (7.26)	1 (1.07)	2 (0.55)
1960--Japan					
54°16'N, 169°36'W	28 June	0	9	0	1
54°38'N, 168°49'W	29 June	0	3	3	1
54°22'N, 169°38'W	30 June	0	2	0	1
Total		0 (2.24)	14 (14.52)	3 (2.13)	3 (1.11)
1961--Japan					
55°00'N, 170°10'W	20 June	0	6	2	1
55°11'N, 169°50'W	21 June	0	8	5	0
55°00'N, 169°55'W	22 June	0	7	6	0
54°49'N, 169°40'W	23 June	1	7	3	0
Total		1 (1.99)	28 (32.06)	16 (10.54)	1 (1.40)

Table 1.--Continued.

Year, country, and tagging site (lat. and long.)	Date of tagging	Recoveries by fishing district: West side	East side		
		Nushagak	Naknek-Kvichak	Egegik	Ugashik
1964--United States[2/]					
56°29'N, 170°12'W (8)	19 June	0	1	1	0
56°41'N, 169°55'W (9)	20 June	1	2	1	0
Total		1 (1.60)	3 (2.52)	2 (1.24)	0 (0.65)
55°17'N, 166°54'W (10)	21 June	0 (1.07)	1 (1.68)	2 (0.83)	1 (0.43)
56°30'N, 160°20'W (12)	24 June	2 (1.60)	1 (2.52)	1 (1.24)	2 (0.65)
57°06'N, 158°54'W (15)	27 June	2 (2.92)	2 (4.62)	4 (2.27)	3 (1.19)
Total (near shore)		4 (4.52)	13 (12.48)		
57°30'N, 161°07'W (13)	25 June	2 (1.07)	2 (1.68)	0 (0.83)	0 (0.43)
57°44'N, 159°24'W (16)	28 June	2 (1.60)	3 (2.52)	1 (1.24)	0 (0.65)
Total (offshore)		4 (2.66)	6 (7.34)		
1965--United States					
57°00'N, 160°00'W	24 June	4 (6.97)	172 (168.73)	30 (27.99)	6 (8.27)
57°48'N, 158°30'W	27 June	20 (1.28)	18 (31.04)	1 (5.15)	0 (1.52)
57°25'N, 159°12'W	26 June	1	57	13	2
57°32'N, 159°15'W	30 June	0	48	8	4
57°28'N, 159°11'W	30 June	1	47	6	2
57°27'N, 159°03'W	1 July	3	48	17	5
57°30'N, 159°00'W	1 July	3	60	10	4
57°32'N, 159°00'W	2 July	0	81	17	2
57°34'N, 159°04'W	2 July	4	59	9	1
Total		12 (16.84)	400 (407.51)	80 (67.61)	20 (19.98)

[1/] Recoveries are totaled to calculate expected numbers; see method of computing expected numbers in text.

[2/] Numbers in parentheses beside tagging sites are station numbers (see Figure 12).

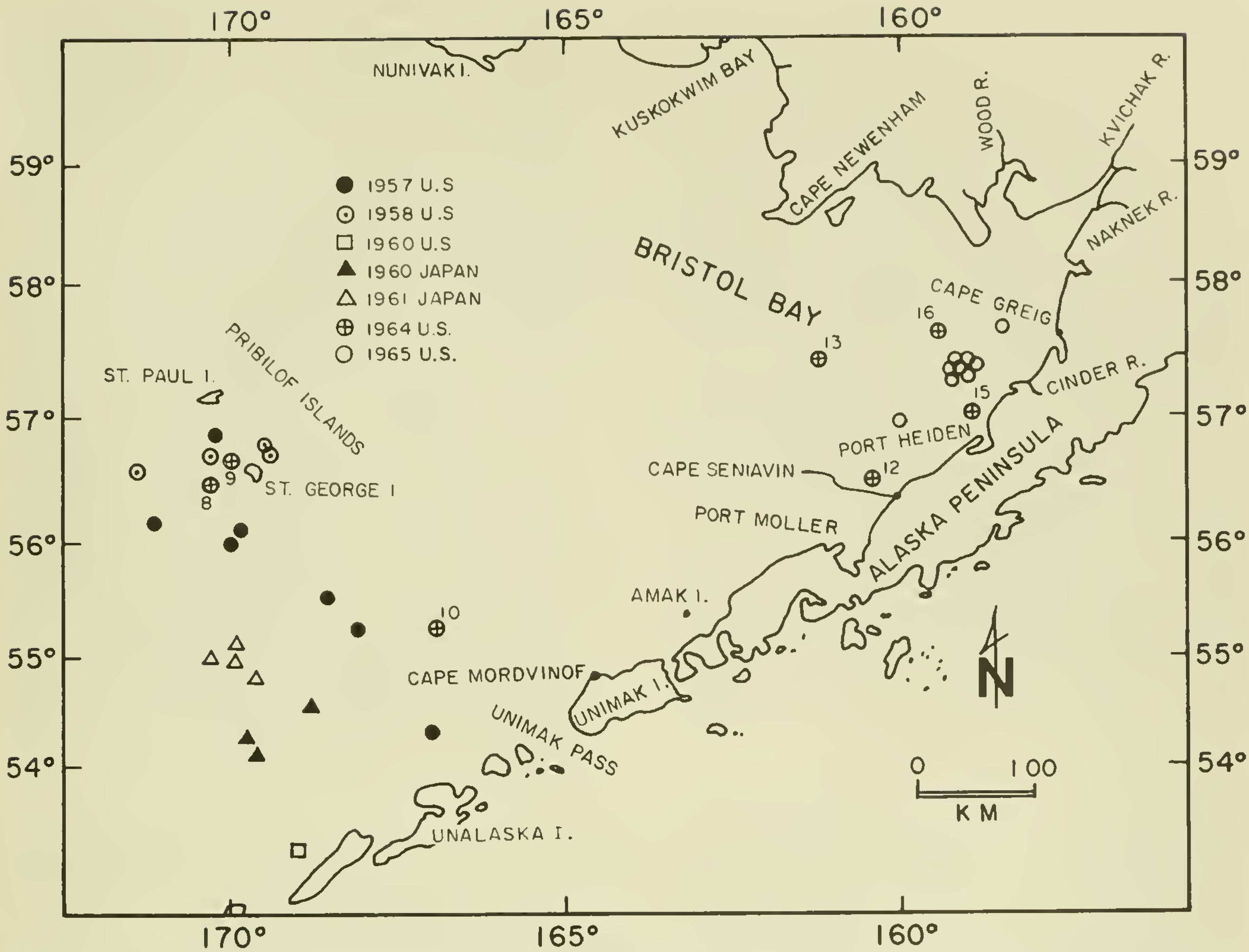

Figure 12.—Areas of tagging by United States and Japan in the 6 yr selected for study to determine the distribution of sockeye salmon stocks in offshore area of Bristol Bay. (See Appendix Table 1 for source of data.)

greater proportion of the .2 fish, which were better able to pass through the gill nets, might be captured; .3 fish were usually held in the net by the gills.

The size composition of sockeye salmon runs to each fishing district in Bristol Bay varies from year to year and between districts in a single year. In some years the run to a given district may be composed largely of the smaller .2 fish. In other years the larger .3 fish may predominate. Large differences between districts in the proportion of .2 and .3 fish could lead to error in interpreting tagging results because of the differences in the vulnerability of tagged fish in these two size groups. No adjustments have been made for the selective action of gill nets in calculating the expected number of tags from each district, and the assumption is made in the analysis that tagged fish in both size groups were as vulnerable to fishing as untagged fish.

Results of Tagging.—The tag recoveries, though few in number and producing only small differences between the actual and expected number of tags recovered in the four Bristol Bay fishing districts (Table 1), are the results of the only significant tagging to be carried out in the Bering Sea and outer Bristol Bay. Therefore, I have used consistencies in the recovery distribution for all 6 yr of tagging as an indication of segregation of individual sockeye stocks in the offshore area. The results of the chi-square analysis to test the hypothesis of like distribution in the offshore area for all sockeye salmon stocks of Bristol Bay origin are given in Table 2.

Except for 1958, the hypothesis of like distribution, i.e., no segregation, for all sockeye salmon stocks of Bristol Bay origin occurring in the eastern Bering Sea is not rejected. A consistent feature in the recovery data for those sockeye salmon tagged in the Bering Sea in 1957, 1958, 1960, 1961, and 1964 (tagging sites 8, 9, and 10, Fig. 12) is the lower-than-expected number of recoveries in the Nushagak fishing district (Table 1). However, except for the 1958 tagging near the Pribilof Islands, differences between the actual and expected numbers of tag recoveries were not large enough to result in significant chi-squares in tests between sockeye salmon stocks from individual fishing districts or between members of stocks captured in fishing districts on the east and west sides of Bristol Bay (Table 2). The significant chi-square obtained in the analysis of the 1958 tag recovery data was largely due to the few Nushagak recoveries and to a lesser extent the more-than-expected Egegik recoveries (Table 1). The few tags recovered from the taggings at sites near the Pribilof Islands in 1964 (sites 8 and 9, Fig. 12) did not result in significant chi-squares and is in contrast to the results of the 1958 tagging in the same area.

Tagging in outer Bristol Bay in 1964 at stations 12, 13, 15, and 16 (Fig. 12) was closer to the mouths of the major river systems, where one might expect more segregation of individual stocks. Tagging stations 12 and 15 were near shore, and stations 13 and 16 were well offshore. For these reasons tag recoveries from each of the four stations were treated individually and then combined as nearshore and offshore tagging (Table 1). In all tests the differences between the actual and the expected number of tag recoveries were not sufficient to result in significant values of chi-square (Table 2), and the hypothesis of like distribution for all sockeye salmon stocks is not rejected.

Although the data are weak because of the few tags recovered from taggings at stations 12, 13, 15, and 16, the distribution of the tag recoveries suggests that segregation of individual stocks may be beginning in this region of Bristol Bay. For example, recoveries in the Egegik and Ugashik districts (Table 1) were about equal to or were greater than the expected number from the tagging at station 12 (inshore), but no recoveries were made from the offshore tagging at station 13 (offshore). Also recoveries from the Naknek-Kvichak district were less than expected from fish tagged at station 12 but about as expected from fish tagged at station 13. Recoveries from Nushagak Bay were about as expected from tagging at station 12 and greater than expected from tagging at station 13.

My interpretation of the data from the outer two stations is as follows: Ugashik and Egegik fish are present at station 12 nearshore but not at station 13 offshore, an indication that these stocks are beginning to leave the offshore waters and move toward their home-river systems on the east side of Bristol Bay. This would decrease the proportion of Naknek-Kvichak stocks at station 12 near shore. The number of Naknek-Kvichak recoveries from tagging at station 12 was, in fact, less than expected (Table 1). The actual number of Naknek-Kvichak recoveries from station 13 is close to the expected number and indicates

Table 2.--Summary of chi-square analysis of recovery data for tags released in the eastern Bering Sea and outer Bristol Bay by the United States and Japan between 1957 and 1965. (See Fig. 12 for location of release sites.)

Year of tagging and country	Release sites of tags recovered	Results of chi-square tests: Between fishing districts (df = 3)		Between east and west side districts (df = 1)	
		Chi-square	Probability	Chi-square	Probability
1957--United States	All release sites (grouped)	3.56	0.331	0.87	0.380
1958--United States	All release sites (grouped)	13.58	<0.005	9.48	<0.005
1960--United States	53°25'N, 168°51'W	4.89	0.195	0.39	0.543
1960--Japan	All release sites (grouped)	5.83	0.129	1.52	0.228
1961--Japan	All release sites (grouped)	3.95	0.273	0.13	0.729
1964--United States	Stations 8 and 9 (grouped)	1.43	0.703	0.08	0.788
	Station 10	3.75	0.302	0.41	0.529
	Station 12	3.88	0.283	0.70	0.428
	Station 13	2.14	0.550	0.24	0.600
	Station 15	5.85	0.128	0.08	0.788
	Station 16	0.89	0.826	0.70	0.428
	Stations 12 and 15 (grouped)	8.53	0.038	0.0001	>0.900
	Stations 13 and 16 (grouped--offshore)	2.46	0.487	0.36	0.564
1965--United States	57°00'N, 160°00'W	2.07	0.565	0.91	0.368
	57°48'N, 158°30'W	240.54	<0.005	267.48	<0.005
	Remaining release locations (grouped)	3.88	0.283	1.16	0.296

that stocks of sockeye salmon bound for these river systems are still abundant in the offshore waters. Although the differences are slight, the recovery data indicate that Nushagak Bay stocks are more abundant offshore (station 13) than inshore (station 12).

Tagging stations 15 and 16 are closer to the head of Bristol Bay (Fig. 12), and Ugashik and Egegik recoveries from station 15 (nearer shore) were substantially greater than expected (Table 1). Ugashik and Egegik recoveries from station 16 (offshore), on the other hand, were almost lacking. This is the same pattern that resulted from taggings at stations 12 and 13 farther seaward. Likewise the returns of Naknek-Kvichak and Nushagak stocks tagged at stations 15 and 16 are like those of taggings at stations 12 and 13, i.e., these stocks are still mostly offshore (station 16) rather than inshore (station 15).

Finally, comparisons of the tag recoveries from the east districts (Naknek-Kvichak, Egegik, and Ugashik combined) with those from the west district (Nushagak) further suggest that segregation of stocks is taking place as the fish progress toward the inner bay. The recoveries from nearshore taggings (stations 12 and 15) in the combined three east districts and the single west district were near the expected number (Table 1). Recoveries from the offshore taggings (stations 13 and 16) were greater than the number expected in the Nushagak district (west side) and less than the number expected in the combined east side districts (Table 1). These differences, however, were not great enough to result in rejection of the hypothesis of like distributions for sockeye salmon stocks destined for fishing districts on each side of Bristol Bay.

All the tagging in 1965 was done within Bristol Bay in three general areas: (1) lat. 57°N and long. 160°W (most seaward); (2) lat. 57°48′N and long. 158°30′W (nearest the head of the bay); and (3) opposite Port Heiden—actually seven closely adjacent locations midway between areas one and two (Fig. 12, Table 1).

Again, the results of chi-square tests of the recovery distributions from the taggings at lat. 57°N and long. 160°W and from the taggings opposite Port Heiden (Table 2) did not result in rejection of the hypothesis of like distributions of all stocks. Recoveries in the Nushagak district were less than expected, but recoveries in the Naknek-Kvichak district occurred in about the numbers expected. Recoveries in the Egegik district were about as expected from tagging at lat. 57°N and long. 160°W but were considerably more abundant than expected from the seven grouped taggings. Differences from the expected number of recoveries in the Ugashik district were not great. A comparison between east and west side fishing districts shows that recoveries from the west side (Nushagak Bay) were fewer than expected. These results and those from the 1964 taggings farther offshore (stations 13 and 16 in Table 1) indicate that sockeye salmon stocks bound for the Nushagak district (west side) were more abundant at the offshore tagging sites toward the west side of the bay than at the inshore sites toward the east side.

The distribution of the recoveries from fish tagged at lat. 57°48′N and long. 158°30′W (near Cape Greig, the most easterly of the offshore tagging sites) differs from the distribution of recoveries from fish tagged more seaward in 1965 (Table 1). Significant chi-squares were obtained for comparisons both between individual fishing districts and between east and west side districts (Table 2), and are cause for rejection of the hypothesis of like distribution for all stocks in the area of tagging. The high chi-square values are due to the much greater-than-expected number of recoveries from the Nushagak Bay district and the substantially smaller-than-expected number of recoveries from the Naknek-Kvichak district. This distribution of recoveries suggests that stock segregation is occurring toward the head of the bay, and appears consistent with the results farther offshore. The Cape Greig tagging site (lat. 57°48′N and long. 158°30′W) is offshore and comparable to sites 13 and 16—Fig. 12). My interpretation of this pattern is that by the time migrating salmon have progressed this far up the bay, most of the Egegik and Ugashik fish have gone inshore, as have many fish of the Naknek-Kvichak stocks, and many of the remaining offshore fish are bound for the Nushagak district.

Synopsis: Segregation of Sockeye Salmon Stocks in the Eastern Bering Sea and Outer Bristol Bay.—The distribution of recoveries of sockeye salmon tagged in the offshore area between long. 165° and 170°W and south of lat. 57°N (Fig. 12) were consistent in showing that fish bound for the four major fishing districts were present in the tagging area in proportion to their abundance in the total run to Bristol Bay. In only one instance (1958) was the hypothesis of like offshore distributions for all stocks rejected. In most cases, the results also showed that stocks of sockeye salmon bound for the Nushagak fishing district occurred at tagging locations in numbers less than expected. Although exploratory fishing has shown substantial numbers of sockeye salmon occur north of lat. 57°N, only limited tagging was carried out in this area and too few tags were recovered to make an analysis.

The recoveries from the tagging at sites inside Bristol Bay (between long. 158° and 161°W—Fig. 12) showed that Nushagak district stocks were present in expected or greater-than-expected numbers at the northernmost tagging sites. Sockeye salmon bound for the Nushagak district may also be more abundant than expected in the eastern Bering Sea. Apparently, the more northerly portion of the area encompasses their migration route, but data to substantiate this point are lacking. For the present, the stock composition of sockeye salmon in the northern portion of the approach to Bristol Bay remains open to question.

The recoveries of sockeye salmon tagged between long. 158° and 161°W showed an increase in the segregation of stocks toward the head of the bay. Fish bound for the Nushagak and Naknek-Kvichak fishing districts were still abundant in the offshore tagging areas toward the head of the bay. Those bound for the Ugashik and Egegik districts, however, were less abundant at offshore locations and apparently had already moved toward the coast and the mouths of their home-river systems.

Inshore Distribution

The distribution of individual sockeye salmon stocks in the inshore area of Bristol Bay was determined from unpublished data from tagging experiments and related studies I conducted in inner Bristol Bay in 1955-57 and 1959. The tagging sites were located within and adjacent to the four regulatory fishing districts in the inshore area: Nushagak, Naknek-Kvichak, Egegik, and Ugashik. Tagged fish were recovered by the commercial fishery within these districts. Some tagged fish were seen at weirs or from towers located on the major river systems entering each fishing district. Tagging was not carried out in all of the districts during the 4 yr of the study; the schedule was as follows: 1955—Naknek-Kvichak and Egegik (Fig. 13); 1956—all four districts (Figs. 14 and 15); 1957—Naknek-Kvichak (Fig. 16); and 1959—Nushagak (Fig. 17).

Unfortunately, no sockeye salmon were tagged in a large area in the middle of the inner bay, and in analyzing the tag recovery data I therefore infer the stock composition of fish in that region from the results of both the offshore and inshore tagging.

One additional method was used to show the distribution of sockeye salmon stocks in 1955. The age group (2.3, 1.3, 1.2, etc.) of each fish tagged at seven sites in the Naknek-Kvichak and Egegik fishing districts (Fig. 13) was determined from scale readings. I used the age group structure of the fish tagged at each site to aid in explaining the distribution of Naknek-Kvichak and Egegik River sockeye salmon stocks in the inshore area.

Capturing and Tagging Fish and Recovery of Tags.—The sockeye salmon for tagging were captured in linen or nylon drift gill nets of the type (13.97-cm stretch measure, 28 meshes deep) commonly used in the Bristol Bay commercial fishery during the years of tagging.

Fish were marked with serially numbered red, blue, green, white, and yellow Petersen disk tags used in various color combinations so that the date and location of tagging could be determined from visual observations.

Recoveries of tags in the 4 yr of the study included actual recaptures and visual sightings of tagged fish. Actual recaptures were obtained from the commercial gill net fishery operated in each district, the personal-use gill nets operated on the major rivers above the gill net fishery, and the spawning grounds. The visual sightings were made either from weirs built across some of the major rivers or from towers located on each bank of the other rivers. Observations were made from these structures of tagged fish in the daily escapement to each major river system. Placards displaying tag color combinations were placed at the counting gates of each weir and at each tower to facilitate positive identification of tagged salmon.

Analysis of Recovery Data.—I used the tag recoveries from the Nushagak, Naknek-Kvichak, Egegik, and Ugashik fishing districts and the observations of the tags sighted in the escapements to the individual river systems to show the distribution in inner Bristol Bay of the stocks of sockeye salmon bound for the four river systems. In addition, the fishery recoveries from the 1959 tagging in Nushagak Bay were grouped according to location of capture within the Nushagak district. For this purpose the district was divided into five subdistricts, and the distribution of fish from each tagging site within these subdistricts was used to show the distribution of each stock contributing to the total run to the Nushagak district.

Because the commercial catch of sockeye salmon within the four fishing districts is composed of mixed stocks, the distribution of tagged fish in the escapement is a better indicator of the final destination of fish released at various sites in inner Bristol Bay than the distribution of tagged fish caught in the fishing districts. Fish recaptured in the fishing districts have been included in the analysis, however, because they serve to complement the results shown by the distribution of tags in the escapement. When viewed with the distribution of tags in the escapement, the distribution of tags in the fishing districts aids in interpreting the movement of individual sockeye salmon stocks within these districts. In addition, both types of tag recovery distributions indicate that the mixing of several nondistrict stocks within a given fishing district was not serious enough to prevent interpretation of the distribution and migration routes of individual sockeye salmon stocks in inner Bristol Bay.

I made several assumptions in interpreting the tag recovery data: First, sockeye salmon of each river system are assumed to be tagged in proportion to their abundance in the area of tagging. If significant mixing of stocks of two different ocean age groups (.2 or .3) occurred in that area of tagging, the selective action of the gill nets (page 7) used to capture fish for tagging could have resulted in a larger proportion of one stock being caught and tagged than were actually present. In general, the recovery distributions resulting from tagging at several of the same locations but in different years were similar. The magnitude of the run as well as the size composition varied between fishing districts in these years. The similarity of distributions for different years indicates that such mixing of stocks

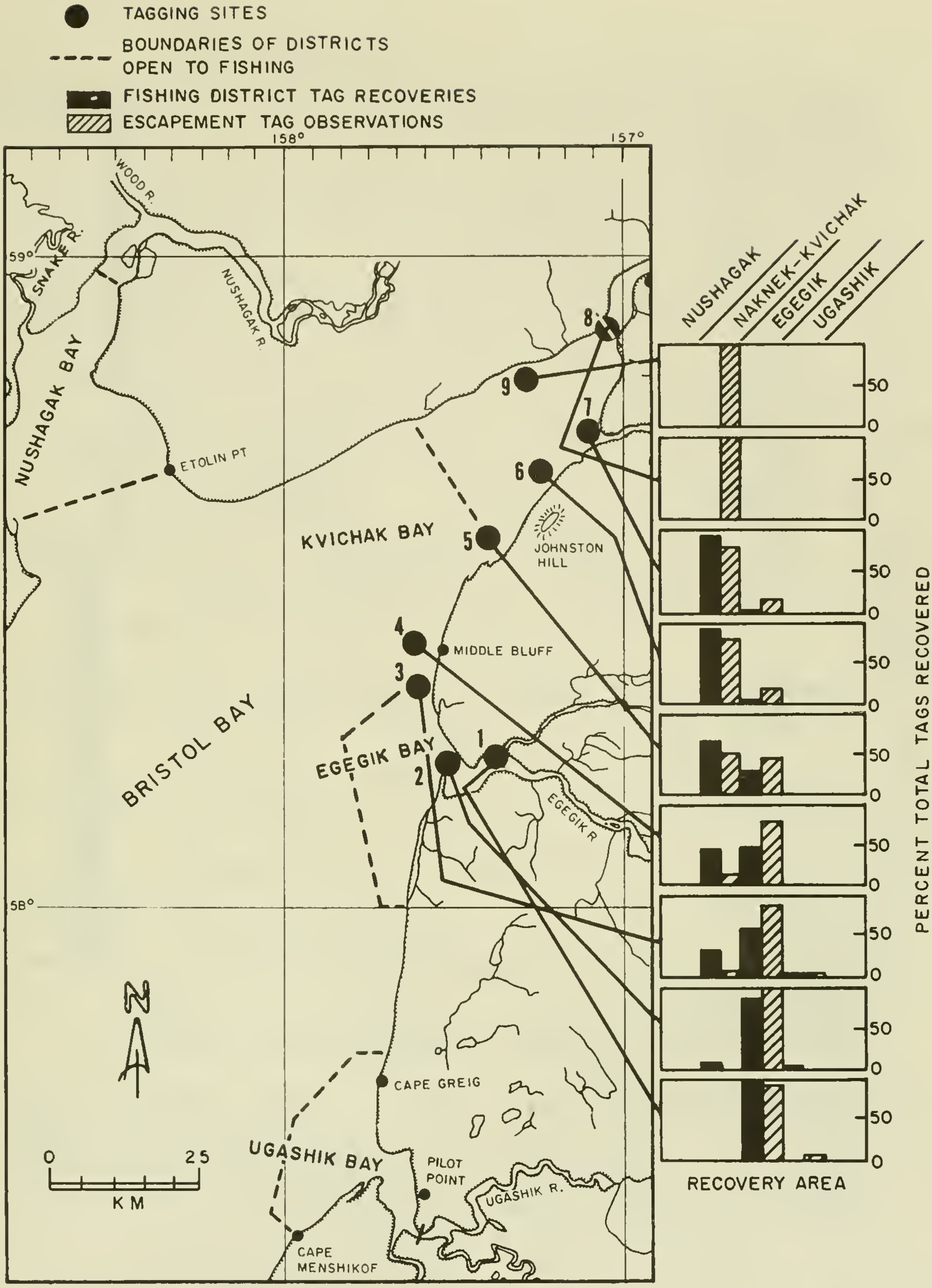

Figure 13.—Distribution of tags recovered in catch (commercial fishery) and observed in the escapements from sockeye salmon released at nine tagging sites in Naknek-Kvichak and Egegik fishing districts (inshore area) in 1955.

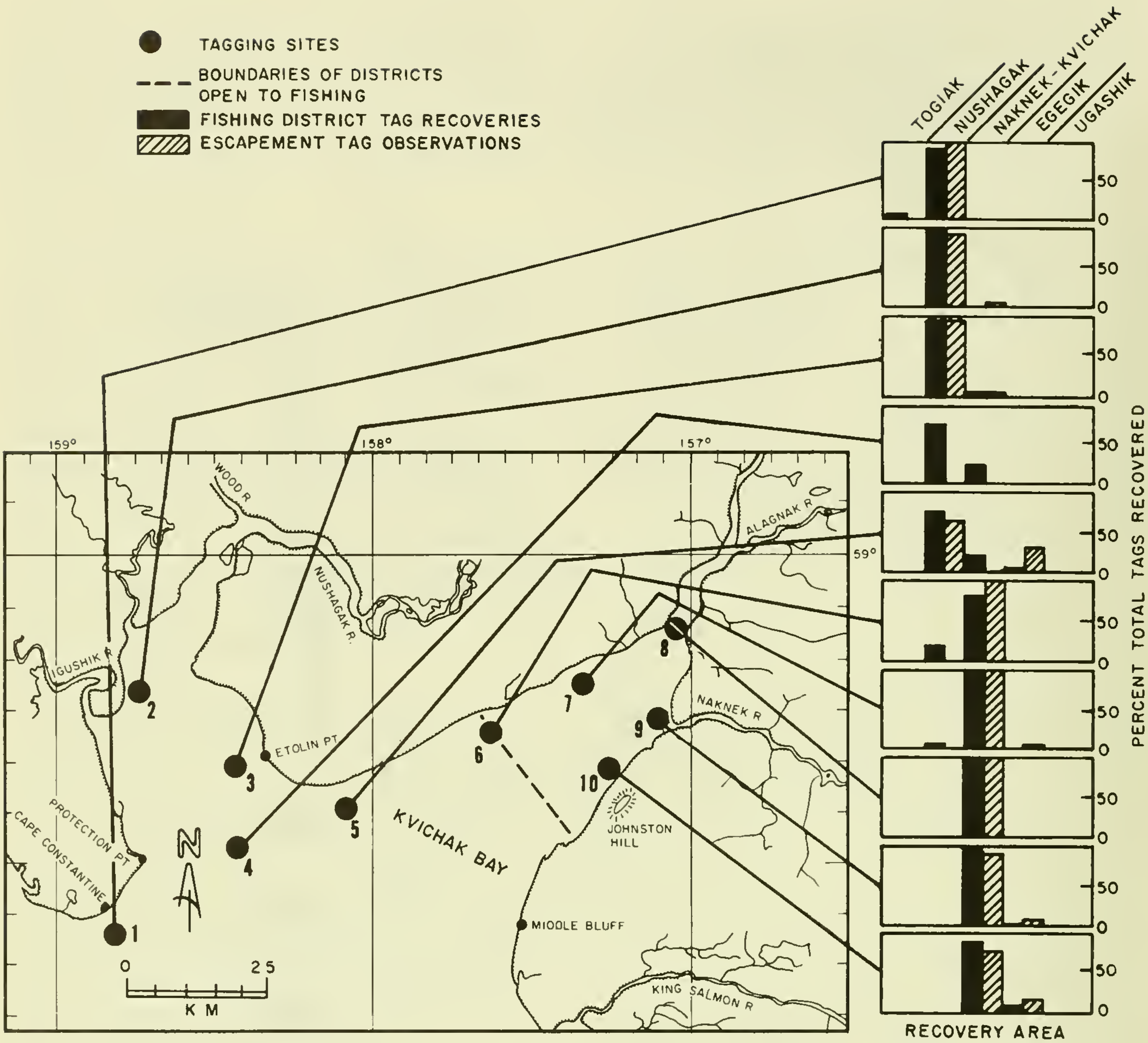

Figure 14.—Distribution of tags recovered in catch (commercial fishery) and observed in the escapements from sockeye salmon released at 10 tagging sites in Nushagak and Naknek-Kvichak districts (inshore area) in 1956.

of different ocean age was not serious enough to prevent interpretation of the distribution of individual stocks in inner Bristol Bay.

A second assumption is that the proportion of each stock at a given tagging location remained essentially the same throughout the duration of the sockeye salmon run into Bristol Bay. This assumption is necessary because I have grouped the recoveries from all taggings at each site (regardless of the date when the fish were tagged) so that I would have enough tags for analysis, particularly in 1955, 1956, and 1959.

In most years and at most tagging sites, fish were tagged during the 2-wk period when sockeye salmon runs to each fishing district reached their maximum intensity. Therefore, I consider the apparent distribution of individual sockeye salmon stocks in inner Bristol Bay resulting from my analysis to represent the major portion of the run to each district.

A third assumption made in analyzing the tagging data is that tagged fish recaptured in each district had an equal likelihood of being reported to investigators. There was no reason to expect a variation in reports from fishermen in each district of the tagged fish captured and therefore no reason to question the validity of this assumption.

The final assumption is that each tagged fish in the escapement had an equal likelihood of being observed and identified as to its location of tagging. It was

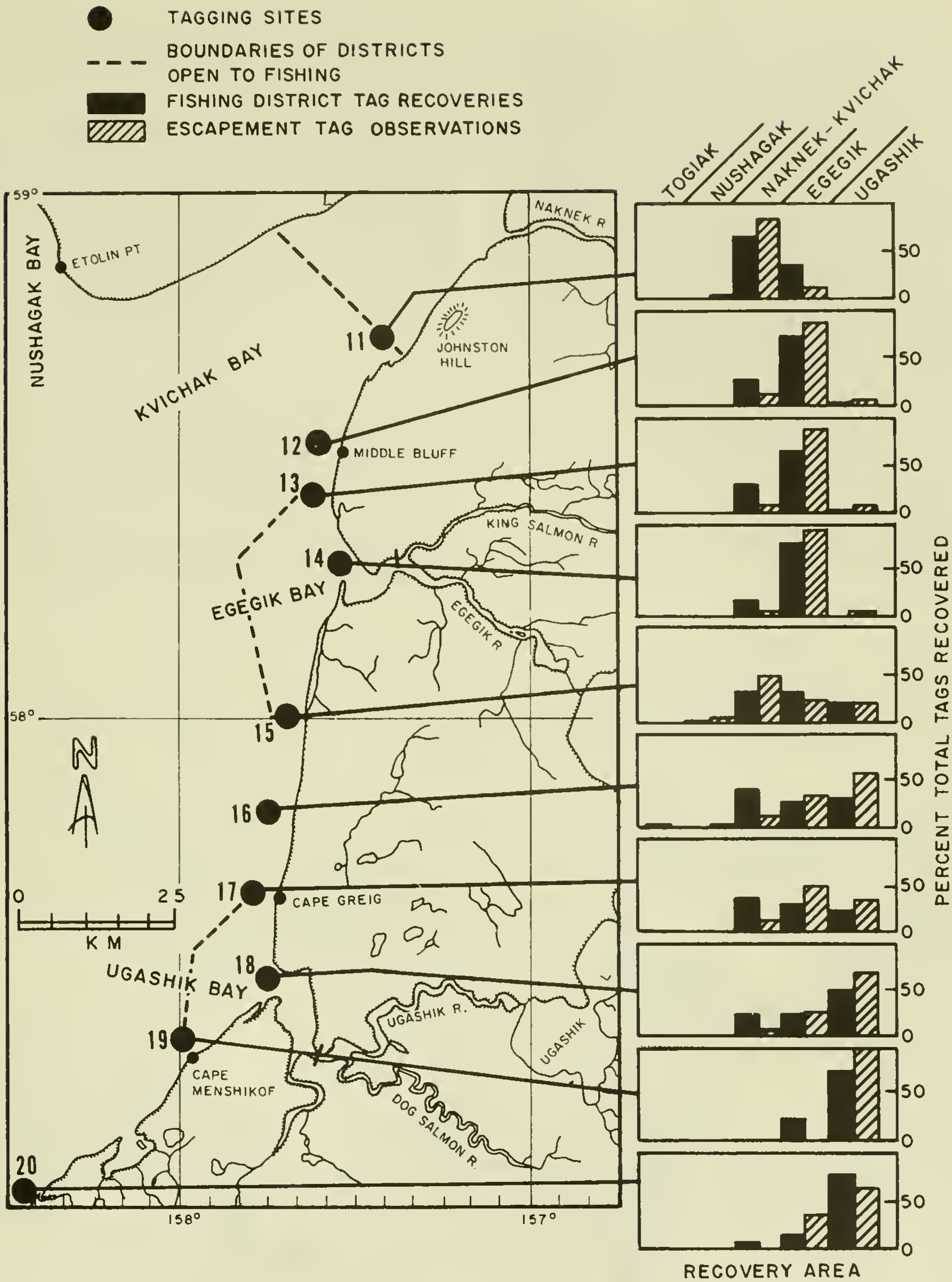

Figure 15.—Distribution of tags recovered in catch (commercial fishery) and observed in the escapements from sockeye salmon released at 10 tagging sites in Naknek-Kvichak, Egegik, and Ugashik fishing districts (inshore area) in 1956.

necessary to ascertain the color of the tag on each side of the fish to determine where the fish had been tagged. At the weirs this was a relatively simple task, because the observer sat directly over an opening through which each fish had to pass and both sides of the fish could be seen easily. Identifying the color of the tag on both sides of a fish from a tower was more difficult, however. The observer did not sit directly over the fish as they moved upstream, and if the fish were some distance from shore, the observer could identify the color of the tag on only one side. Therefore, rivers with weirs probably had a higher proportion of tagged fish identified correctly than did rivers covered by towers. Because of such factors as the magnitude of the run and turbidity of the water, the ability to identify tagged fish from towers also varied from day to day, between river systems, and from year to year. The numbers of fish bearing each tag color combination observed in the spawning escapement to each river system have not been adjusted for possible differences in the ability of observers to identify the color of both tags. When viewing the recovery distribution in the discussion of the tagging results, the reader should keep this point in mind. The actual number of tags in the spawning escapement to rivers where tags were observed from towers was probably higher than is shown in the results.

Interpretation of Tagging Results.—Recoveries and visual observations of the tagged fish released at sites within and adjacent to the four regulatory fishing districts in the inshore area in 1955, 1956, 1957, and 1959 (Figs. 13-17) are used in this section to show the distribution of major sockeye salmon stocks. The number of tagged fish recovered in the commercial fishery in the inshore area and those observed in the escapement at weirs, towers, or on the spawning grounds on the five major sockeye salmon river systems of Bristol Bay are listed in Appendix Tables 2-7.

The relative sizes of the runs (catch plus escapement) to each of the inshore fishing districts in the 4 study years (Table 3) must be taken into account when drawing inferences about the distribution of each major sockeye stock from the distribution of tagged fish because the size of the runs to each district varies from year to year. Tag recoveries have not been weighted for size of run because, as will become ap-

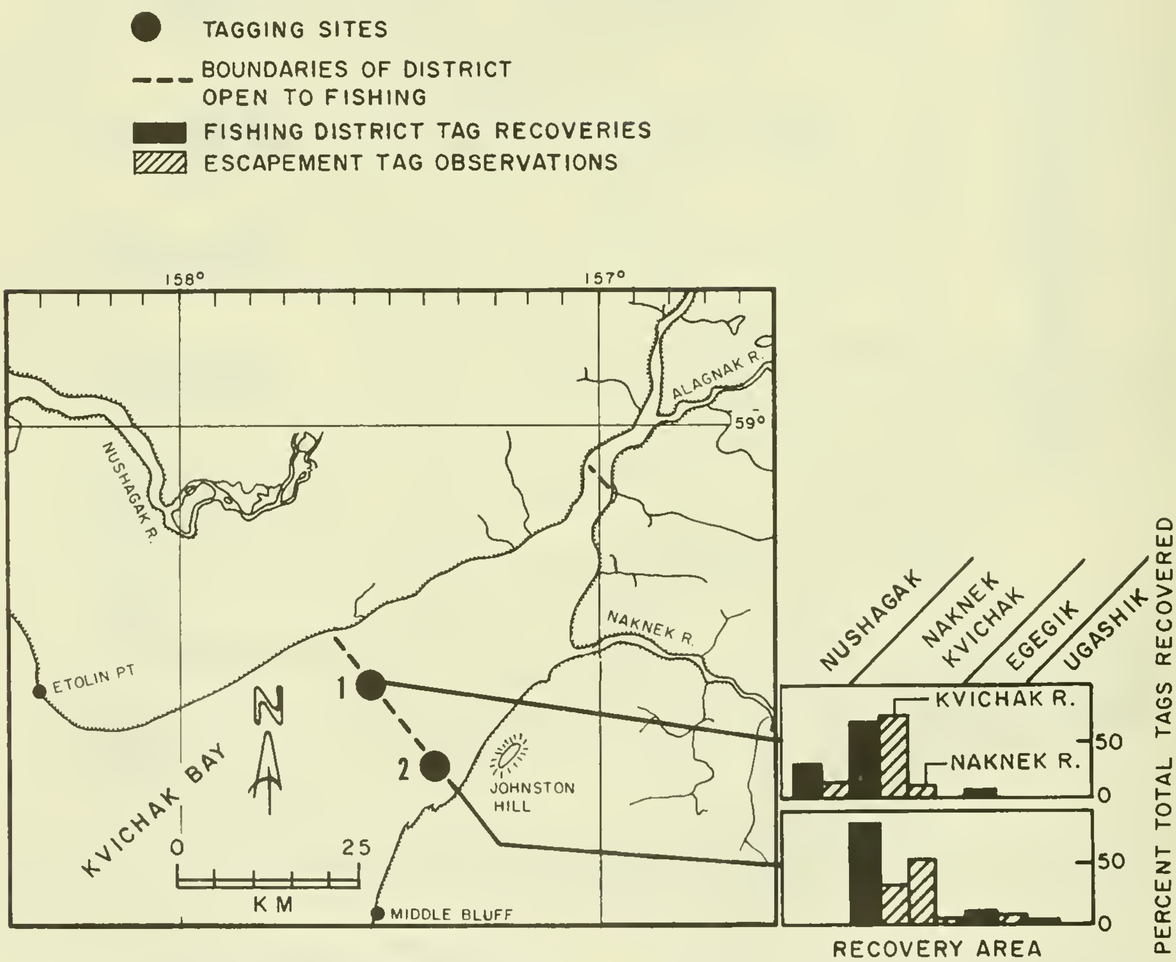

Figure 16.—Distribution of tags recovered in catch (commercial fishery) and observed in the escapements from sockeye salmon released at two tagging sites in Naknek-Kvichak fishing districts (inshore area) in 1957.

parent in the discussion below, the recorded catch for each district was composed of stocks destined for the river systems of several fishing districts. The contribution of each stock to the commercial catch of a fishing district will vary from year to year depending on the relative size of the individual runs. Assignment of portions of the catch in each fishing district to individual river systems was not done in 1955 and 1956, but it was done in 1957 and 1959. These apportionments were based on the age composition of the spawning escapement of each river system. The age composition of the escapement, however, has been modified to a certain extent because of the selective action of the gill nets (see page 7). The mixing of stocks within fishing districts, however, was not considered serious enough to prevent use of the size of the total run in interpreting the distribution of tagged fish for the 4 yr of study. In most years large escapements to individual rivers occurred when large catches were made within the fishing district (Table 3).

Distribution of Sockeye Salmon Stocks Occurring on the East and West Side of Inner Bristol Bay.—The distribution of tags recovered in the commercial fishery and observed in the spawning escapement (Figs. 13-17) showed that sockeye salmon stocks

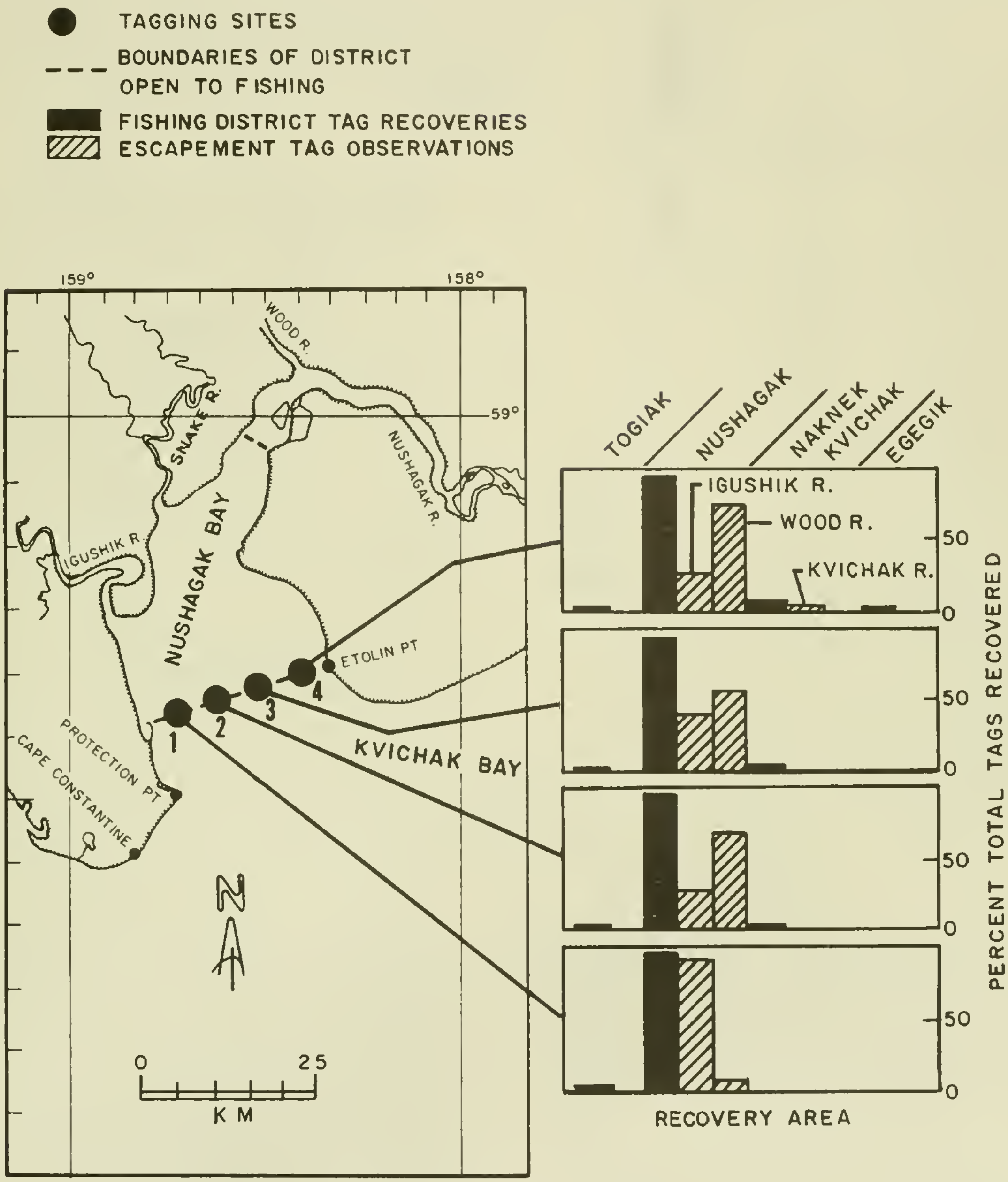

Figure 17.—Distribution of tags recovered in catch (commercial fishery) and observed in the escapements from sockeye salmon released at four tagging sites in Nushagak fishing district (inshore area) in 1959.

Table 3.--Total run (commercial catch plus escapement) of sockeye salmon (thousands of fish) to four inshore fishing districts of Bristol Bay, 1955, 1956, 1957, and 1959,[1] and ratio of each district's stocks to Naknek-Kvichak district stocks.

Item	1955	1956	1957	1959
Naknek-Kvichak district				
Catch	2,564	5,988	4,579	1,689
Escapement				
Kvichak River	250	9,440	2,840	680
Alagnak River	170	780	120	820
Naknek River	280	1,770	630	2,230
Total run	3,264	17,978	8,169	5,419
Nushagak district				
Catch	1,055	1,263	491	1,720
Escapement				
Wood River	1,380	720	290	2,210
Igushik River	(2/)	(2/)	(2/)	3/644
Nushagak River	550	440	210	3/49
Snake River	(2/)	(2/)	(2/)	4/137
Total run	2,985	2,423	991	4,760
Ratio to Naknek-Kvichak stocks	1:1.09	1:7.41	1:8.24	1:1.14
Egegik district				
Catch	622	1,187	814	662
Escapement	270	1,100	390	1,070
Total run	892	2,287	1,204	1,732
Ratio to Naknek-Kvichak stocks	1:3.66	1:7.86	1:6.78	1:3.13
Ugashik district				
Catch	241	341	351	423
Escapement	240	340	350	220
Total run	481	681	701	643
Ratio to Naknek-Kvichak stocks	1:6.79	1:26.40	1:11.65	1:8.43

1/Source: Kasahara (1963, p. 53 and 79).

2/Data not available.

3/Unpublished data on file National Marine Fisheries Service, Auke Bay Fisheries Laboratory, Auke Bay, AK 99821.

4/This figure was determined by subtracting the sum of the Igushik and Nushagak River escapements from 830, the figure given by Kasahara (1963, p. 79) for the total escapement of all river systems in Nushagak Bay except the Wood River.

from the west side of inner Bristol Bay were not appreciably mixed with stocks from the east side. Very few fish tagged in the vicinity of Nushagak Bay (sites 1-5 in 1956 (Fig. 14) and sites 1-4 in 1959 (Fig. 17)) were captured in the fishing districts on the east side of the bay or observed in the escapement to river systems on the east side. Few fish tagged on the east side of Bristol Bay were captured in the Nushagak Bay fishery or observed in the escapement to Nushagak Bay river systems (Figs. 13-16). Some mixing of Nushagak and Kvichak Bay stocks occurred on the west side of Kvichak Bay between Etolin Point and the outer boundary of the Naknek-Kvichak fishing district (Figs. 14, 16, and 17). The observations of tagged fish in the escapements indicated that the mixed stocks on the west side of Kvichak Bay were primarily from the Wood and Kvichak Rivers (Figs. 16-18).

Results of the offshore tagging in 1964 and 1965 showed that Ugashik and, to a lesser extent, Egegik sockeye salmon tagged in outer Bristol Bay between long. 158° and 151°W (Fig. 12) were leaving the offshore waters for the coast on the east side of Bristol Bay and the mouths of their home-river systems. Few fish tagged on the west side of Kvichak Bay were taken in the Egegik or Ugashik fishing districts or observed in the spawning escapements of these river systems (Figs. 13, 14, and 16). The area in the middle of inner Bristol Bay between Nushagak and Egegik Bays must be the main migration route of sockeye salmon bound for the Kvichak and Naknek River systems.

Distribution of Ugashik River Sockeye Salmon in Inner Bristol Bay.—The most extensive tagging of sockeye salmon near the Ugashik River was carried out in 1956 (Fig. 15). Ugashik fish were dominant at sites 16, 18, 19, and 20, whereas Egegik fish were dominant at sites 15 and 17. Most of the sockeye salmon tagged and released south of the entrance to Ugashik Bay were recovered in the Ugashik fishery and escapement. Some sockeye salmon tagged as far north as the outer boundary of the Naknek-Kvichak fishing district were also recovered in the Ugashik fishery in 1955 (Fig. 13) and 1957 (Fig. 16). A small number of sockeye salmon tagged off Middle Bluff in 1955 (Fig. 13) and 1956 (Fig. 15) were recovered in the Ugashik fishery and observed in the Ugashik River escapement.

When the relative sizes of the sockeye salmon runs to the Naknek-Kvichak, Egegik, and Ugashik fishing districts (Table 3) are considered in viewing the tag recovery distribution, it is apparent that the Ugashik River sockeye salmon were the most abundant stock in the nearshore area between sites 15 and 20 (Fig. 15). Although significant numbers of fish tagged at sites 18, 17, and 16 were recovered in the Naknek-Kvichak fishery, relatively few were observed in the escapement of the Naknek and Kvichak River systems (Fig. 15). This suggests that only a small number of fish were actually Naknek and Kvichak River stocks. A large number of these tagged fish were observed in the Egegik and Ugashik River escapements (Fig. 15), however, which indicates that these fish were predominantly Egegik and Ugashik sockeye salmon. The proportion of Ugashik fish increased toward the entrance to Ugashik Bay. The Naknek-Kvichak sockeye salmon run in 1956 was more than 26 times the size of the Ugashik run and almost 8 times that of the Egegik run (Table 3).

Distribution of Egegik River Sockeye Salmon in Inner Bristol Bay.—Although some Egegik River

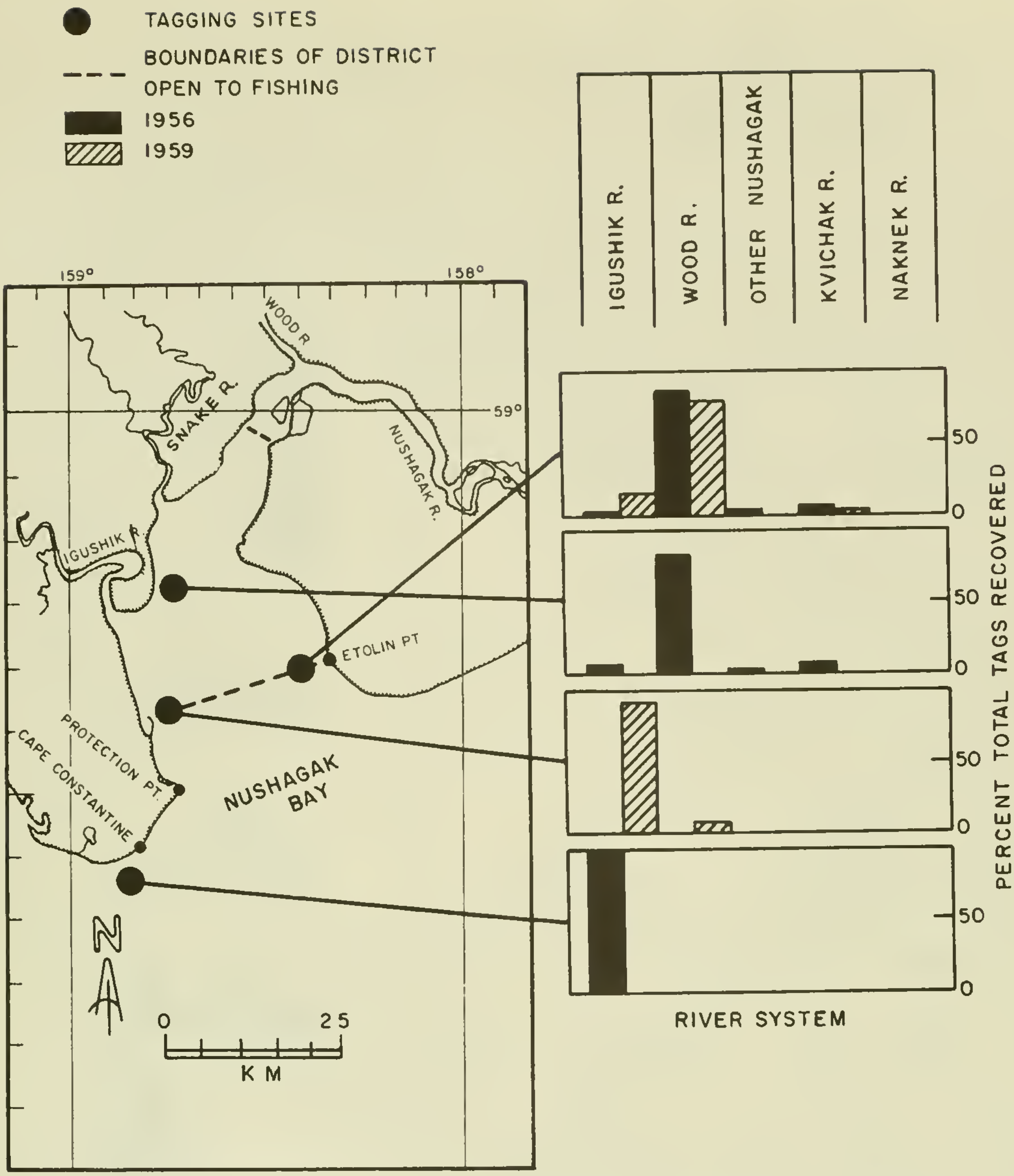

Figure 18.—Distribution of tagged sockeye salmon in the Igushik, Wood, Kvichak, Naknek, and other Nushagak Bay river escapements, Bristol Bay, 1956 and 1959.

sockeye salmon were present at almost every tagging site on the east side of the bay, they were most abundant in the area between Middle Bluff (site 12) and Ugashik Bay (site 18) (Fig. 15). The escapement distribution of sockeye salmon tagged in 1956 (Figs. 14 and 15) showed that some fish of the Egegik River stock were present in the area between the entrance to Ugashik Bay and the mouth of the Naknek River. The distribution of fish tagged in 1955 (Fig. 13) also showed that fish bound for the Egegik River occurred off the mouth of the Naknek River. With the exception of tagging site 5 in 1956, few fish tagged on the west side of inner Bristol Bay (Fig. 14) were captured in the Egegik fishing district or observed in the spawning escapement of the Egegik River system.

Of fish tagged in the area between the outer east side boundary of the Naknek-Kvichak fishing district and Middle Bluff, there was a marked increase in recoveries in the Egegik fishery and observed in the Egegik River escapement (Figs. 13 and 15). This was particularly apparent in the escapement distribution of fish tagged off Middle Bluff and at the outer southeast side boundary of the Naknek-Kvichak fishing district in both 1955 and 1956 (Fig. 19). In 1956 the sockeye salmon run to the Naknek-Kvichak district was almost eight times the run to the Egegik

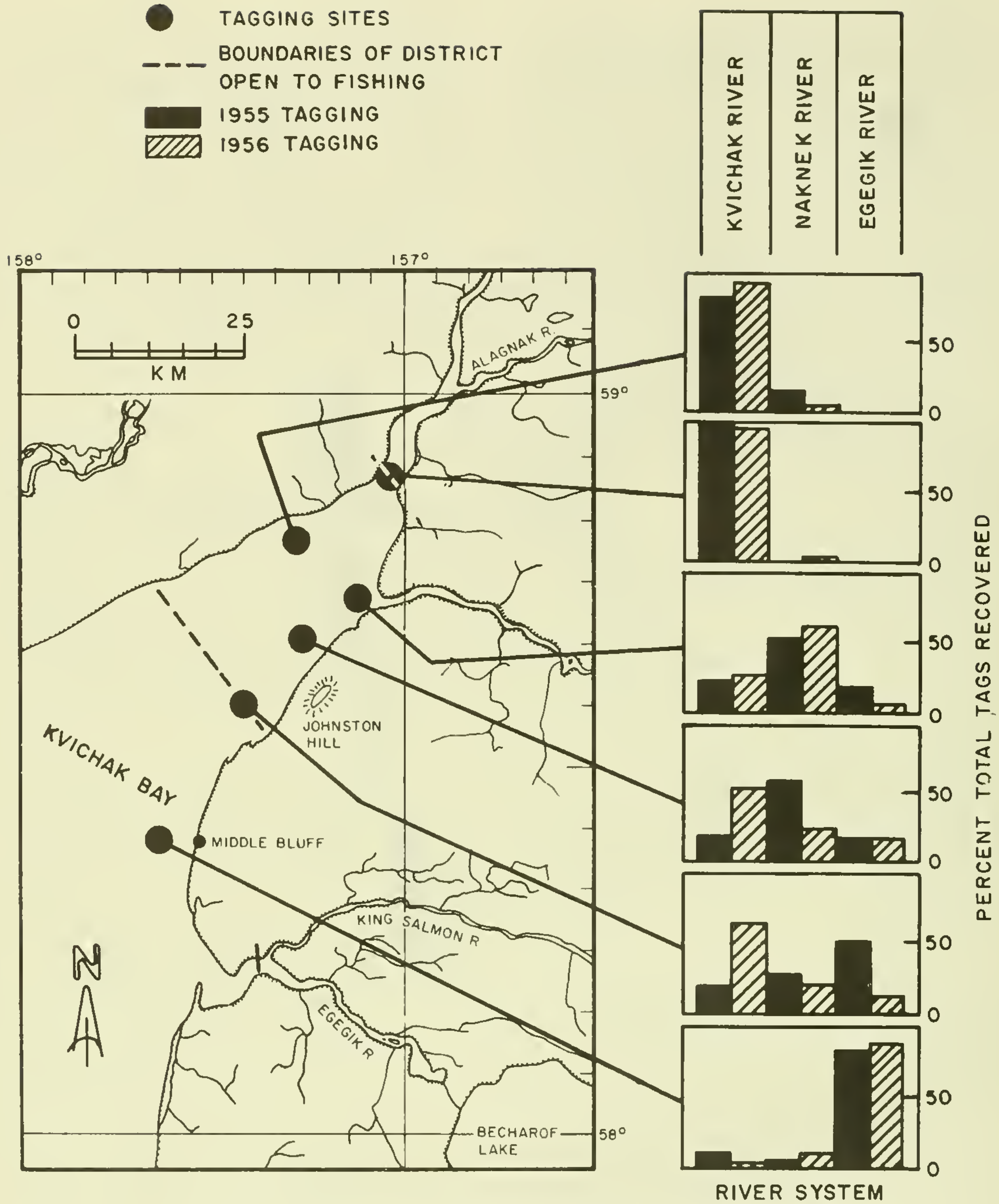

Figure 19.—Distribution of tagged sockeye salmon in the Kvichak, Naknek, and Egegik River escapements, Bristol Bay, 1955 and 1956.

system (Table 3); in 1955 it was only about four times as large. In both years, however, the numbers of tagged fish observed in the escapement to the Egegik system alone and combined Naknek and Kvichak systems were similar (Figs. 13 and 15). In both years, many fish tagged off Middle Bluff were captured in the Naknek-Kvichak fishing district, but only a few were observed in the escapement to the two rivers (Fig. 19). Many of these tagged fish, however, were observed in the escapement to the Egegik River (Fig. 19), which indicates that most fish tagged off Middle Bluff and recovered in the Naknek-Kvichak fishing district were actually Egegik fish.

In 1956 and 1957 significantly more of the fish tagged at the east side boundary of the Naknek-Kvichak fishing district were observed in the Naknek and Kvichak River escapements than in the Egegik River escapement (Figs. 16 and 19). Of the fish tagged at the same location in 1955, the number observed in the Naknek and Kvichak River escapements (Fig. 13) was only slightly higher than the number observed in the Egegik River escapement. This was probably due to the smaller runs of sockeye salmon to the Naknek and Kvichak Rivers in 1955 than in 1956 and 1957 (Table 3), so that a greater proportion of fish of Egegik origin were probably taken in the Naknek-Kvichak fishing district in 1955 than in 1956 or 1957.

Fishery recoveries and escapement observations of sockeye salmon tagged between Middle Bluff and the entrance to Egegik Bay showed that Egegik River fish were the most abundant stock in this area (Figs. 13 and 15). The runs of Naknek and Kvichak River fish outnumbered Egegik fish in all years of tagging, but probably were offshore and outside this tagging area. The recoveries of sockeye salmon tagged at the outer east side boundary of the Naknek-Kvichak fishing district, however, showed that Naknek and Kvichak River fish became the most abundant stocks in the nearshore area north of Middle Bluff. Most Egegik River fish apparently left the offshore waters for the coast and their home-river system south of the outer boundary of the Naknek-Kvichak fishing district.

The recoveries of sockeye salmon tagged south of the entrance to Egegik Bay in 1956 (Fig. 15) showed that Egegik fish were abundant in the coastal areas as far south as the entrance to Ugashik Bay. Egegik River sockeye salmon were probably the most abundant stock north of site 15 (Fig. 15), while Ugashik River fish, as pointed out above, were the most abundant in the area between tagging sites 18 and 16. Most fish bound for the Naknek, Kvichak, and Alagnak rivers were apparently farther offshore outside the area of tagging.

Distribution of Naknek and Kvichak River Sockeye Salmon in Inner Bristol Bay.—Sockeye salmon tagged as far south as the entrance to Ugashik Bay on the east side of inner Bristol Bay were recovered in the Naknek-Kvichak fishing district and observed in the Kvichak River escapement (Fig. 15). Sockeye salmon tagged on the west side of Kvichak Bay (Fig. 16) and in outer Nushagak Bay off Etolin Point (Fig. 14) were recovered in the Naknek-Kvichak fishing district and observed in the Kvichak River escapement. The results of the taggings discussed thus far, however, have shown that the main migration route of sockeye salmon bound for the Naknek and Kvichak River systems was offshore outside the area of tagging on both the east and west sides of inner Bristol Bay. Naknek and Kvichak River sockeye salmon stocks become abundant in the coastal waters only north of Middle Bluff on the east side and northeast of Etolin Point on the west side of Kvichak Bay. In this region, Kvichak Bay is only about 32.3 km wide and Naknek, Kvichak, and Alagnak River stocks probably occupy the entire area during the migration to their home-river systems.

The escapement recoveries of fish tagged in 1955 and 1956 at the same locations on the east and west sides of Kvichak Bay (Fig. 19) indicates that sockeye salmon on the west side of the bay were largely Kvichak River stocks. Most of the escapement observations of fish tagged on the west side of the bay were made in the Kvichak River system but a few were made in the Naknek River system. The results were similar for sockeye salmon tagged at site 1 on the west side of Kvichak Bay in 1957 (Fig. 16).

The escapement distribution of fish tagged on the east side of Kvichak Bay between the Naknek River mouth and the outer boundary of the Naknek-Kvichak fishing district indicated that a mixture of Naknek, Kvichak, and Egegik stocks occurred there (Figs. 13-15). More fish from these taggings were observed in the Naknek River system than in the Kvichak River system in 1955 (Fig. 19), indicating a greater abundance of Naknek fish in the area of tagging.

This dominance of Naknek River sockeye salmon in the area of tagging is also reflected in the age composition of fish tagged at sites 1 through 7 in 1955 (Fig. 20). The age composition of sockeye salmon in the escapements to the Naknek, Kvichak, and Egegik Rivers differed significantly in 1955. These differences are discussed here as supporting evidence for my interpretation of the distributions of Naknek, Kvichak, and Egegik stocks based on the results of inshore tagging. The dominant age groups in the escapements were: 2.3 in the Egegik River, 1.3 in the Naknek River (Fig. 20), and 1.2 in the Kvichak River. The proportion of the 2.3 and 1.3 age groups at each tagging site changed between the mouth of the Egegik and Naknek Rivers (Fig. 20). The 2.3 age group decreased in abundance north of the Egegik River mouth, and the 1.3 age group increased in abundance. This showed a change from the Egegik River stock to predominantly Naknek River stock, consistent with the results of tagging discussed above.

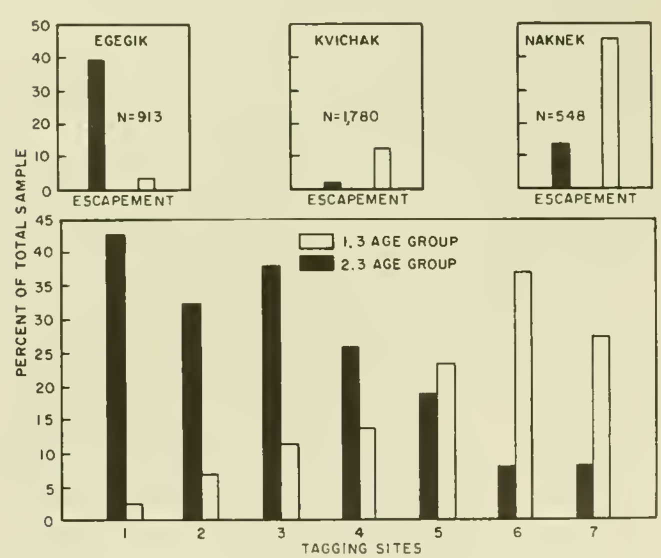

Figure 20.—Distribution in the spawning escapement of 1.3 and 2.3 age groups of sockeye salmon tagged at seven sites in the Naknek-Kvichak and Egegik fishing districts in 1955. (See Fig. 13 for location of tagging sites.)

With the exception of the tagging off the Naknek River mouth, more fish from the 1956 taggings along the east side of Kvichak Bay (Figs. 14 and 15) were observed in the Kvichak River escapement than in the Naknek River escapement. In 1956 the escapement to the Kvichak River system was more than five times that to the Naknek River system (Table 3). This greater abundance of Kvichak River sockeye salmon would explain why more Kvichak River fish than Naknek River fish were tagged on the east side of Kvichak Bay. Naknek stocks, however, were still more abundant on the east side than on the west side of Kvichak Bay in 1956.

The escapement distribution of sockeye salmon tagged at site 2 on the east side of Kvichak Bay in 1957 (Fig. 16) showed that Naknek River fish were more abundant than Kvichak River fish in this area. Although the run to the Naknek-Kvichak fishing district in 1957 was about half as large as in 1956, the relative sizes of the escapements to the Naknek and Kvichak Rivers (Table 3) indicated that Kvichak River stocks again dominated this run. Kvichak River fish were apparently not as abundant in the nearshore waters on the east side of Kvichak Bay in 1957 as they were in 1956; as a result, a higher proportion of Naknek fish were probably tagged in this area in 1957.

The foregoing results illustrate three points about the distribution of sockeye salmon stocks in Kvichak Bay. First, Kvichak and Wood River stocks occurred together along the west side of Kvichak Bay between Etolin Point and the outer boundary of the Naknek-Kvichak fishing district. Second, a mixture of primarily Naknek and Egegik River stocks occurred along the east side of Kvichak Bay. Third, the stock composition changed from principally Naknek River sockeye salmon on the east side of the bay to mainly Kvichak River sockeye salmon on the west side.

Distribution of Nushagak Bay Sockeye Salmon Stocks in Inner Bristol Bay.—Escapement observations of sockeye salmon tagged in 1956 and 1959 (Figs. 17 and 18) indicated the individual stocks comprising the run to Nushagak Bay were already segregated to a certain extent before entering this bay. This was particularly true for the Wood and Igushik River stocks and may also be true for the Snake River stocks.

The recovery distribution of the sockeye salmon tagged in 1959 at the entrance to Nushagak Bay (Fig. 17) showed Igushik River fish were the most abundant stock on the west side of the bay, while Wood River fish appeared to be the most abundant stock on the east side of the bay. More fish tagged at site 1 on the west side of Nushagak Bay were observed in the Igushik River escapement than in the Wood River escapement and more fish tagged at sites 2, 3, and 4 were observed in the Wood River escapement than in the Igushik River escapement.

The apparent segregation of the individual sockeye salmon stocks comprising the run to Nushagak Bay is also indicated by the fishery recoveries of fish tagged at sites 1-4 in 1959. The tags recovered within the Nushagak fishing district were grouped by tagging site and subdistrict in which they were recovered (Fig. 21). A high proportion of the fish tagged at sites 1 and 2 were caught in a subdistrict encompassing the Igushik River mouth; most of these fish were recaptured in the set and drift gill nets operated within or close to the Igushik River mouth. Most of the recaptures of sockeye salmon tagged at sites 3 and 4 were from subdistricts on the east side of Nushagak Bay. As shown above, more sockeye salmon tagged at sites 3 and 4 were observed in the Wood River escapement than in the escapement to the other river systems, indicating that the Wood River stock moved through Nushagak Bay principally on the east side.

In spite of the dominance of Wood River stocks in 1959 and the smaller amount of fishing effort on the west side of Nushagak Bay, most of the fish that were tagged at site 1 and recaptured were recaptured on the west side of Nushagak Bay. Wood River stocks generally make up the greater portion of the total run to Nushagak Bay. For example, in 1959 the Wood River escapement was more than three times the Igushik escapement (Table 3), and over 75% of the fishing effort in 1959 (estimated from aerial surveys of the fishery) was concentrated in the eastern half of Nushagak Bay, which is the area of greatest fishing success. The proportion of tagged fish observed in the escapement was significantly higher for fish from site 1 than for fish from the other three sites (Appendix Table 7), and probably reflects the smaller amount of fishing effort on the west side of Nushagak Bay.

The escapement distribution of sockeye salmon tagged off Etolin Point in 1956 was similar to that of the fish tagged in this location in 1959 (Fig. 18), which suggests that sockeye salmon on the east side of Nushagak Bay were primarily Wood River stocks. No fish tagged off Cape Constantine in 1956 were observed in Wood or Nushagak River escapements (Fig. 18). Eighteen fish tagged off Cape Constantine in 1956 were captured in set gill nets near the mouth of the Igushik River, which indicates that they were destined for the Igushik Lake spawning grounds. Few fish from the 1956 tagging north of the Igushik River mouth (Fig. 18) were recaptured in set nets in the Igushik River. Most of these tagged fish were observed in the Wood River (Fig. 18), which indicates that Igushik River fish were not abundant north of the river but probably went directly up the Igushik River after they entered Nushagak Bay.

My interpretation of the distribution of the individual stocks in the sockeye salmon run to Nushagak Bay is as follows: (1) Igushik River fish are already segregated, to a certain extent, from Wood River stocks before they enter Nushagak Bay; (2) the main migration route of Igushik River fish is in the nearshore area around Cape Constantine, along the west side of Nushagak Bay, and up the Igushik River; and (3) Wood River fish, and probably those of the

Consideration of the results of the exploratory fishing and tagging studies in the inshore and offshore areas in their entirety yields a reasonable picture of the distribution and migratory routes of the major stocks of adult sockeye salmon bound for Bristol Bay. The exploratory fishing in the eastern Bering Sea east of long. 170°W (Fig. 2) showed that the main migration route of sockeye salmon returning to Bristol Bay is in the offshore waters of the southern half of Bristol Bay (Fig. 11). Exploratory fishing and the offshore and inshore tagging studies showed that Bristol Bay stocks remain in the offshore waters until they are within 32 to 80 km of the mouths of their home-river systems.

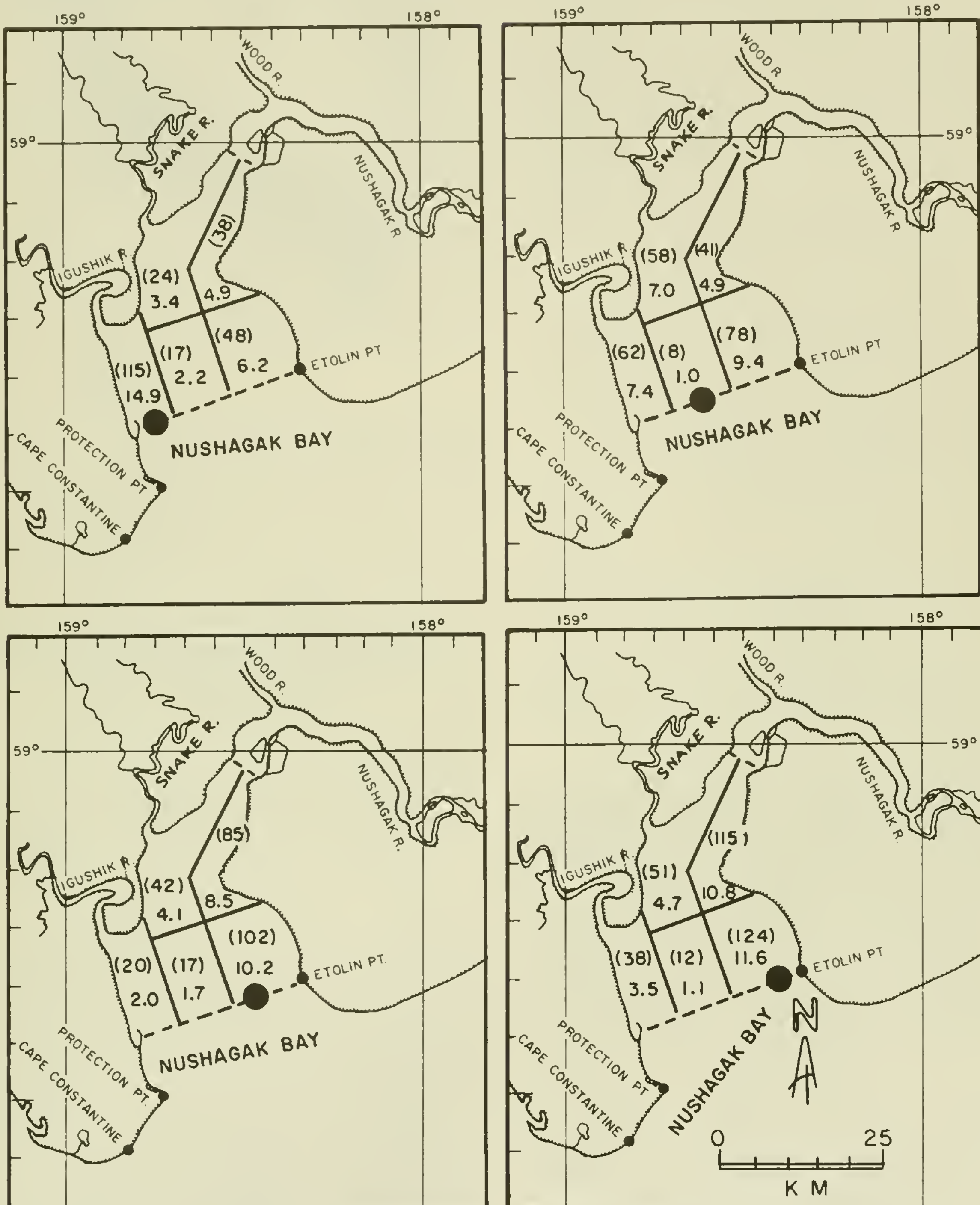

Figure 21.—Percentage distribution of recoveries within the Nushagak fishery of sockeye salmon tagged at four sites in the Nushagak district. Numbers of tags recovered in parentheses; decimal numbers are percentages of total tags recovered. (See Fig. 18 for location of tagging sites.)

Snake and Nushagak Rivers, too, occur farther offshore in the Cape Constantine area. Therefore, these three stocks must enter Nushagak Bay in the middle and on the east side of the bay during migration to their home-river systems.

The results of the 1959 tagging in Nushagak Bay suggest that a substantial number of sockeye salmon tagged near the middle of the bay (site 2—Fig. 17) were bound for the Snake River system. The proportion of tagged fish observed in the escapements of the Wood and Igushik Rivers was significantly lower for fish from site 2 than sites 1, 3, and 4 (Appendix Table 7). Because the proportion of fishery recaptures of tagged fish was essentially the same for all four sites (Appendix Table 6), removal of tagged fish by the fishery was not regarded as the cause of the lower proportion of tagged fish from site 2 in the escapement. Fishery recaptures of fish tagged at site 2 were equally abundant on the east and west sides of Nushagak Bay (Fig. 21), even though the fishing effort on the east side of Nushagak Bay was considerably greater than on the west side. This indicates that more fish tagged at site 2 were on the west side than on the east side and consequently more of the fish should have escaped the fishery to be observed in the spawning escapement. A plausible explanation for their absence in the escapement is that they went to some river system not adequately searched for tagged fish.

Reliable observations of tagged sockeye salmon were not made in the Nushagak River escapement, but five tags were recovered in the personal-use gill nets in the main Nushagak River. The personal-use fishery is well above the commercial fishery and below the escapement enumeration towers. The recovered fish were from taggings at sites 2, 3, and 4 (Appendix Table 7) in the middle and on the east side of Nushagak Bay.

The Snake River system was not checked for tags until late August, when it was discovered it had received an unusually large escapement. Most of the sockeye salmon in the Snake River escapement spawn on the beaches of Nunavaugaluk Lake (Fig. 1). High winds and rough water during a 3-day survey of this lake hampered observations of the spawning fish, but three tags were positively identified. Two of the fish had been tagged at site 2 and one at site 3. These observations are too few to be conclusive, but they do suggest the distribution noted previously here, i.e. Snake River fish are most abundant on the west side and in the middle of Nushagak Bay.

Synopsis: Segregation of Sockeye Salmon Stocks in the Inshore Region of Bristol Bay.—In Figure 22, I present a generalized picture of the probable migration routes of various stocks of sockeye salmon as they move through Bristol Bay after leaving the Bering Sea. Additional tagging is needed in both the nearshore and offshore waters on the north and west sides of Bristol Bay.

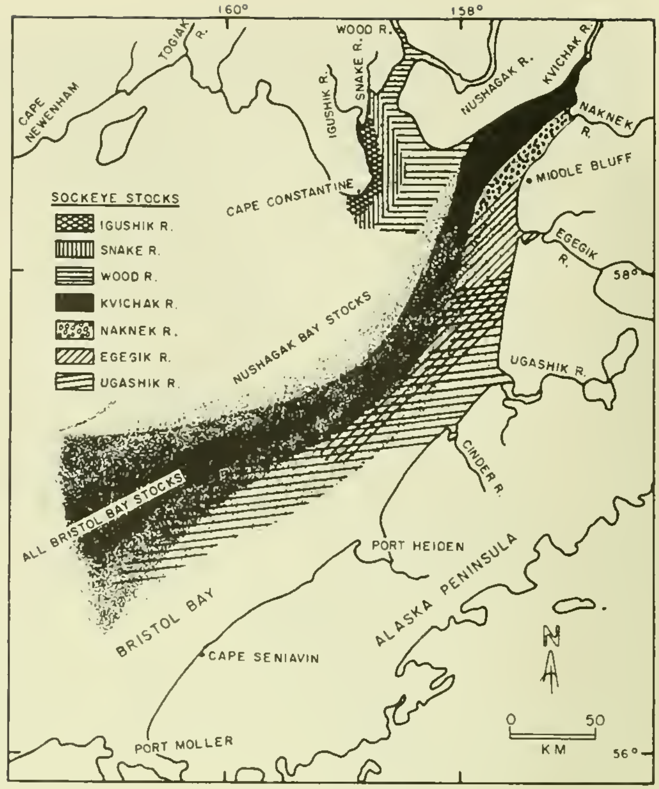

Figure 22.—General distribution of Bristol Bay stocks of sockeye salmon, showing areas of greatest stock abundance.

SYNOPSIS OF DISTRIBUTION AND MIGRATORY ROUTES OF SOCKEYE SALMON IN THE EASTERN BERING SEA AND BRISTOL BAY

There were no statistically significant differences in the distributions of the major stocks of sockeye salmon destined for the fishing districts of Bristol Bay between long. 171° and 167°W (Fig. 11). Stocks bound for Nushagak Bay appeared to be more abundant in the northerly approaches to Bristol Bay, but the results are inconclusive. The distribution of stocks in the eastern Bering Sea between long. 167° and 161°W also remains open to question. In the area between Port Moller and Cape Newenham, however, stocks appeared to become segregated into those destined for rivers entering on the west and those entering on the east sides of Bristol Bay. Sockeye salmon migrating to Kvichak Bay were abundant in the offshore waters in the southern half of Bristol Bay. Stocks bound for Nushagak Bay were abundant in the offshore waters farther north. Stocks bound for the Ugashik and Egegik Rivers declined in abundance in the offshore waters and increased near to shore on the east side of Bristol Bay. The tagging in outer Bristol Bay between long. 161° and 158°30′W showed that stock segregation continued toward the head of Bristol Bay (Fig. 22).

The results of the tagging in the nearshore areas on the west and east sides of inner Bristol Bay also showed an increase in stock segregation (Fig. 22). Nushagak Bay sockeye salmon became the most abundant stocks on the west side of inner Bristol Bay, and Ugashik and Egegik River fish the most abundant stocks on the east side of the inner bay. From this distribution, I concluded that Naknek, Kvichak, and Alagnak River fish mostly remained in the offshore waters until they reached Kvichak Bay in the area northeast of Middle Bluff.

The various sockeye salmon stocks in the run to Nushagak Bay became segregated to a certain extent before they entered that bay. The Igushik River stock was most abundant in the nearshore area off Cape Constantine and along the west side of Nushagak Bay to the Igushik River mouth. The data suggest that Snake River fish were most abundant along the west side and in the middle of Nushagak Bay. The Wood River stock was most abundant on the east side of the bay, indicating this stock and probably the Nushagak River stock enter en masse on the east side and in the middle of Nushagak Bay.

Ugashik sockeye salmon were also declining in abundance in the offshore waters of outer Bristol Bay and increasing in abundance nearer to shore on the east side of inner Bristol Bay. South of lat. 58°N Ugashik River fish increased in abundance, becoming most abundant in the nearshore area south of the entrance to Ugashik Bay.

Sockeye salmon bound for the Egegik River system were declining in abundance in the offshore waters of outer Bristol Bay as far seaward as long. 159°W. They apparently reached the coastal area in greatest abundance between Middle Bluff and lat. 58°N.

Naknek and Kvichak River sockeye salmon were also segregated from each other by the time they entered Kvichak Bay. Fish bound for the Kvichak River were most abundant on the west side and in the middle of Kvichak Bay. Naknek River fish were most abundant in the nearshore waters on the east side of Kvichak Bay northeast of Middle Bluff.

SUMMARY

1. The results of the exploratory fishing operations in the eastern Bering Sea and outer Bristol Bay showed that the main migration route of Bristol Bay sockeye salmon is in the offshore waters of the south half of the entrance to the bay and in the south half of the bay itself. This migration route is illustrated on a chart of the area.

2. Offshore tagging studies showed that there was little segregation of the individual stocks of Bristol Bay sockeye salmon in the eastern Bering Sea and outer Bristol Bay as far as a line between Port Moller and Cape Newenham. Toward the head of the bay from this line, there was a progressive segregation of sockeye salmon stocks according to their river system of origin. This segregation appeared to begin while these fish were still as much as 200 km from the mouths of their home-river systems.

3. Inshore tagging studies showed a continuation of stock segregation toward the head of Bristol Bay. Those sockeye salmon stocks originating in the river systems of Nushagak Bay became most abundant on the west side of inner Bristol Bay. They appeared to be somewhat segregated before entering Nushagak Bay. Ugashik and Egegik River sockeye salmon became the most abundant stocks on the east side of the inner bay. Naknek, Kvichak, and Alagnak river sockeye salmon stocks remained offshore until they reached Kvichak Bay in the area northeast of Middle Bluff. These results are illustrated on a chart of Bristol Bay.

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Appendix Table 1.--Dates of exploratory fishing or tagging and source of data used to show the distribution and migration route of sockeye salmon in the offshore area of Bristol Bay.

Date	Source of data
	Exploratory Fishing
27 June-23 July 1939	Barnaby (1952), Table 4, Page 12
6 June-3 July 1940	Barnaby (1952), Table 7, Page 16
17-21 June 1940	Barnaby (1952), Table 9, Page 17
7-11 July 1941	Barnaby (1952), Table 16, Page 20
17-28 June 1958	International North Pacific Fisheries Commission (1959), Table 2, Page 75
27 June-3 July 1959	International North Pacific Fisheries Commission (1960), Table 2, Page 82
12-25 June 1961	French (1963), Table 9, Page 100
24 June-6 July 1965	French et al. (1967), Figure 8, Page 79
24 June-6 July 1966	French et al. (1967), Figure 8, Page 79
	Tagging
17-29 June 1957	Hartt (1962)
16-27 June 1958	Hartt (1962)
20 June 1960	Hartt (1966)
28-30 June 1960	Kondo et al. (1965)
20-23 June 1961	Kondo et al. (1965)
19-28 June 1964	Lander et al. (1966)
24 June-2 July 1965	Lander et al. (1967)

Appendix Table 2.--Number and percent[1] of tagged sockeye salmon recovered in catch (commercial fishery) or observed in escapement from fish released at nine sites in Naknek-Kvichak and Egegik districts in 1955. (See Fig. 13 for location of tagging sites.)

		Fish recovered in																			
		Nushagak district				Naknek-Kvichak district[2]						Egegik district				Ugashik district					
								Escapement													
Tagging	No. fish	Catch		Escapement (Wood River towers)		Catch		Kvichak River towers		Naknek River weir		Catch		Escapement (weir)		Catch		Escapement (weir)		Unknown catch	
site	tagged	No.	%	No.	%	No.	%	No.[3]	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
1	77	0	--	0	--	0	--	0	--	0	--	30	39.0	15	19.5	0	--	1	1.3	0	--
2	104	0	--	0	--	4	3.8	0	--	0	--	34	32.7	32	30.8	1	1.0	0	--	1	0.9
3	326	0	--	0	--	44	13.5	3	0.9	3	0.9	87	26.7	75	23.0	4	1.2	2	0.6	0	--
4	386	1	0.3	0	--	79	20.5	6	1.6	3	0.8	84	21.8	56	14.5	2	0.5	1	0.3	1	0.3
5	246	0	--	0	--	79	32.1	6	2.4	8	3.3	38	15.4	14	5.7	1	0.4	0	--	1	0.4
6	121	0	--	0	--	38	31.4	3	2.5	9	7.4	2	1.6	3	2.5	0	--	0	--	0	--
7	131	0	--	0	--	56	42.7	5	3.8	11	8.4	3	2.3	4	3.1	0	--	0	--	0	--
8	[4]14	0	--	0	--	--	--	1	7.1	0	--	--	--	0	--	--	--	0	--	--	--
9	[5]20	0	--	0	--	--	--	5	25.0	1	5.0	--	--	0	--	--	--	0	--	--	--

[1] Percent of total number tagged.

[2] Alagnak River not covered by a tower or weir.

[3] Includes four tags positively identified at tower, 16 recovered from spawning grounds, and nine recovered in Kvichak River above fishery.

[4] Kvichak River above fishery.

[5] Tagging conducted after close of commercial fishing season.

Appendix Table 3.--Number and percent[1] of tagged sockeye salmon recovered in catch (commercial fishery) or observed in escapement from fish released at 20 sites in Nushagak, Naknek-Kvichak, Egegik, and Ugashik districts in 1956. (See Figs. 14 and 15 for location of tagging sites.)

		Fish recovered in																			
		Togiak district[2]				Nushagak district[3]								Naknek-Kvichak district[4]						Egegik district				Ugashik district			
								Escapement								Escapement											
Tagging site	No. fish tagged	Catch		Escapement (survey)		Catch		Wood River towers		Nushagak River survey		Igushik River set gill nets		Catch		Kvichak River towers		Naknek River weir		Catch		Escapement (weir)		Catch		Escapement (weir)	
		No.	%	No.	%	No.	%	No.[5]	%	No.	%	No.	%	No.	%	No.[5]	%	No.[5]	%	No.	%	No.[5]	%	No.	%	No.[6]	%
1	418	11	2.6	0	--	114	27.3	0	--	0	--	18	4.3	0	--	0	--	0	--	0	--	0	--	0	--	0	--
2	205	0	--	0	--	81	39.5	46	22.4	1	0.5	4	1.9	0	--	4	1.9	0	--	0	--	1	0.5	0	--	1	0.5
3	504	0	--	0	--	153	30.4	110	21.8	4	0.8	3	0.6	5	1.0	8	1.6	0	--	0	--	0	--	0	--	1	0.2
4	9	0	--	0	--	3	33.3	0	--	0	--	0	--	1	11.1	0	--	0	--	0	--	0	--	0	--	2	22.2
5	94	0	--	0	--	17	18.1	13	13.8	0	--	0	--	5	5.3	0	--	0	--	1	1.1	9	9.6	0	--	0	--
6	29	0	--	0	--	3	10.3	0	--	0	--	0	--	13	44.8	0	--	3	10.3	0	--	0	--	0	--	0	--
7	348	0	--	0	--	2	0.6	0	--	0	--	0	--	83	23.8	121	34.8	6	1.7	0	--	2	0.6	0	--	0	--
8	332	0	--	0	--	0	--	0	--	0	--	0	--	71	21.4	65	19.6	1	0.3	0	--	0	--	0	--	0	--
9	361	0	--	0	--	0	--	0	--	0	--	0	--	159	44.0	[7] 22	6.1	48	13.3	1	0.2	6	1.7	0	--	0	--
10	511	0	--	0	--	0	--	0	--	1	0.2	0	--	153	29.9	[8] 60	11.7	28	6.1	19	3.7	21	4.1	0	--	0	--
11	461	0	--	0	--	0	--	2	0.4	0	--	0	--	112	24.3	70	15.2	21	4.6	60	13.0	14	3.0	0	--	0	--
12	467	0	--	0	--	0	--	0	--	0	--	0	--	47	10.1	4	0.9	15	3.2	128	27.8	144	30.2	1	0.2	5	1.1
13	251	0	--	0	--	0	--	0	--	0	--	0	--	27	10.8	5	2.0	0	--	59	23.5	54	21.5	3	1.2	3	1.2
14	486	0	--	0	--	0	--	0	--	0	--	0	--	24	4.9	5	1.0	0	--	106	21.8	168	33.9	1	0.2	4	0.8
15	548	0	--	0	--	1	0.2	2	0.4	0	--	0	--	69	12.6	37	6.8	21	3.8	67	12.2	28	5.1	43	7.8	28	5.1
16	379	1	0.3	0	--	0	--	0	--	1	0.3	0	--	53	14.0	7	1.8	3	0.8	36	9.5	24	5.5	39	10.3	47	12.4
17	203	0	--	0	--	0	--	0	--	0	--	0	--	34	16.7	0	--	9	4.4	24	11.8	30	16.3	21	10.3	21	10.3
18	628	0	--	0	--	0	--	0	--	0	--	0	--	48	7.6	6	0.9	0	--	49	7.8	31	4.9	94	15.0	80	12.7
19	97	0	--	0	--	0	--	0	--	0	--	0	--	0	--	0	--	0	--	5	5.1	0	--	15	15.5	24	24.7
20	128	0	--	0	--	0	--	0	--	0	--	0	--	3	2.3	0	--	0	--	7	5.5	10	7.8	35	27.3	19	14.8

[1] Percent of total number tagged.

[2] Limited foot survey of Togiak system.

[3] Igushik and Nushagak River partly covered by foot surveys.

[4] Alagnak River not covered by tower, weir, or foot survey.

[5] Weighted counts.

[6] Includes 16 fish caught in personal-use nets in river 12 miles above fishery.

[7] Includes one tag recovered 18 miles above fishery but below tower site.

[8] One returned from Alagnak system (0.2%).

Appendix Table 4.--Number of tagged sockeye salmon recovered in catch (commercial fishery) from fish released at two sites in Naknek-Kvichak fishing district in 1957. (See Fig. 16 for location of tagging sites.)

Tagging site and date	No. fish tagged	No. fish recovered in: Nushagak district	Naknek-Kvichak district	Egegik district	Ugashik district	Unknown	Total
Site 1							
24 June	4	1	2	--	--	--	3
26 June	15	1	7	--	--	--	8
27 June	16	--	1	1	--	--	2
29 June	4	--	1	--	--	--	1
30 June	9	--	6	--	--	--	6
2 July	13	2	2	--	--	--	4
3 July	9	--	2	--	--	--	2
4 July	40	1	9	--	--	--	10
5 July	45	--	9	1	--	1	11
6 July	8	--	2	--	--	--	2
7 July	26	3	7	--	--	--	10
8 July	85	13	6	--	--	--	19
9 July	20	3	5	--	--	--	8
12 July	3	1	--	--	--	--	1
16 July	6	--	1	--	--	--	1
19 July	6	--	--	--	--	--	--
Total	309	25	60	2	--	1	88
Percent[1]	--	8.1	19.4	0.6	--	0.3	28.5

Appendix Table 4.--Continued.

Tagging site and date	No. fish tagged	No. fish recovered in: Nushagak district	Naknek-Kvichak district	Egegik district	Ugashik district	Unknown	Total
Site 2							
21 June	312	--	131	10	--	9	150
23 June	12	--	6	1	--	1	8
24 June	77	--	24	6	--	3	33
25 June	273	--	120	7	--	3	130
26 June	306	--	138	15	--	6	159
27 June	305	--	127	4	--	7	138
29 June	288	--	113	29	--	14	156
30 June	278	--	123	12	--	5	140
1 July	293	--	101	13	--	6	120
2 July	84	--	28	10	--	2	40
3 July	166	--	70	--	--	4	74
4 July	346	--	152	3	--	10	165
5 July	433	--	152	5	--	10	167
6 July	39	--	17	1	--	--	18
7 July	778	2	310	14	--	17	343
8 July	1,156	2	394	8	--	30	434
9 July	426	--	202	4	--	11	217
12 July	263	--	71	5	--	6	82
13 July	471	--	105	34	--	4	143
14 July	356	1	103	22	--	10	136
15 July	423	1	73	18	1	3	96
16 July	538	1	120	39	--	6	166
17 July	300	--	85	4	--	1	90
18 July	452	--	81	5	--	3	89
19 July	56	--	5	1	--	--	6
20 July	550	--	92	13	1	1	107
22 July	17	--	5	--	--	--	5
23 July	95	--	17	2	--	--	19
24 July	222	--	60	2	--	3	65
Total	9,315	7	3,025	287	2	175	3,496
Percent[1]	--	0.08	32.5	3.1	0.02	1.9	37.5

[1] Percent of total number tagged.

Appendix Table 5.--Number and percent[1] of tagged sockeye salmon observed in escapement from fish released at two sites in Naknek-Kvichak fishing district in 1957. (See Fig. 16 for location of tagging sites.)

Tagging site	Fish observed in: Nushagak district (Wood River towers) No.	%	Naknek-Kvichak district: Kvichak River towers No.	%	Alagnak River towers No.	%	Naknek River weir No.	%	Egegik district (Egegik River towers) No.	%
1	21	6.8	111	35.9	0	--	16	5.2	0	--
2	5	0.0	306	3.3	54	0.6	653	7.0	96	1.0

[1] Percent of total number tagged.

Appendix Table 6.--Number of tagged sockeye salmon recovered in catch (commercial fishery) from fish released at four sites in Nushagak fishing district in 1959. (See Fig. 17 for location of tagging sites.)

Tagging site and date	No. fish tagged	No. fish recovered in Togiak district	Nushagak district	Naknek-Kvichak district	Egegik district	Ugashik district	Total
Site 1							
20 June	13	1	2	--	--	--	3
23 June	18	--	2	--	--	--	2
26 June	61	--	4	--	--	--	4
28 June	82	--	22	--	--	--	22
30 June	86	--	27	--	--	--	27
2 July	122	--	36	--	--	--	36
6 July	185	--	75	--	--	--	75
7 July	27	--	17	--	--	--	17
9 July	33	--	6	--	--	--	6
11 July	60	2	24	--	--	--	26
13 July	72	2	28	--	--	--	30
15 July	12	--	2	--	--	--	2
Total	771	5	245	--	--	--	250
Percent[1/]	--	0.6	31.8	--	--	--	32.4
Site 2							
20 June	11	--	2	--	--	--	2
26 June	110	--	11	--	--	--	11
28 June	31	--	12	--	--	--	12
30 June	330	--	110	3	--	--	113
2 July	223	--	82	--	--	--	82
7 July	19	--	6	--	--	--	6
9 July	66	--	18	--	--	--	18
11 July	15	1	10	--	--	--	11
13 July	20	--	11	--	--	--	11
15 July	8	--	3	--	--	--	3
Total	833	1	265	3	--	--	269
Percent[1/]	--	0.1	31.8	0.4	--	--	32.3

Appendix Table 6.--Continued.

Tagging site and date	No. fish tagged	No. fish recovered in Togiak district	Nushagak district	Naknek-Kvichak district	Egegik district	Ugashik district	Total
Site 3							
21 June	17	--	1	--	--	--	1
25 June	226	1	38	1	--	--	40
27 June	73	--	16	4	--	--	20
29 June	118	2	30	1	--	--	33
1 July	310	--	117	4	--	--	121
3 July	140	--	58	--	--	--	58
8 July	15	--	5	1	--	--	6
10 July	37	--	3	--	--	--	3
12 July	17	--	8	--	--	--	8
14 July	12	--	5	--	--	--	5
Total	965	3	281	11	--	--	295
Percent[1/]	--	0.3	29.1	1.1	--	--	30.6
Site 4							
19 June	5	--	--	--	--	--	--
21 June	5	--	--	--	--	--	--
25 June	12	--	2	--	--	--	2
27 June	19	--	4	1	--	--	5
29 June	18	--	7	--	--	--	7
1 July	343	--	141	4	1	--	146
8 July	11	--	3	1	--	--	4
10 July	413	1	88	5	--	--	94
12 July	206	--	99	1	--	--	100
14 July	39	--	20	--	--	--	20
Total	1,071	1	364	12	1	--	378
Percent[1/]	--	0.09	34.0	1.1	0.09	--	35.3

[1/]Percent of total number tagged.

Appendix Table 7.--Number and percent[1] of tagged sockeye salmon observed in escapement from fish released at four sites in Nushagak fishing district in 1959. (See Fig. 17 for location of tagging sites.)

	Fish observed in											
	Nushagak district								Naknek-Kvichak district			
Tagging site	Igushik River towers[2]		Wood River towers[2]		Snake River[3]		Nushagak River towers		Kvichak River towers		Kuskokwim River[4]	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
1	328	42.5	28	3.6	--	--	--	--	--	--	[5]1	0.1
2	54	6.5	133	16.0	[6]2	0.2	[7]1	0.1	--	--	--	--
3	121	12.5	171	17.7	[6]1	0.1	[7]3	0.3	--	--	--	--
4	48	4.5	236	22.0	--	--	[7]1	0.09	[8]3	0.3	--	--

[1] Percent of total number tagged.

[2] Weighted counts.

[3] Observed on foot surveys.

[4] See Figure 1.

[5] Recovered in gill net near mouth of river.

[6] Spawning ground recaptures by U.S. Fish and Wildlife Service personnel.

[7] Tagged fish recaptured in personal-use gill nets located upstream from the commercial fishing district and downstream from the towers.

[8] Spawning ground recaptures by Fisheries Research Institute personnel.

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